New Scientist

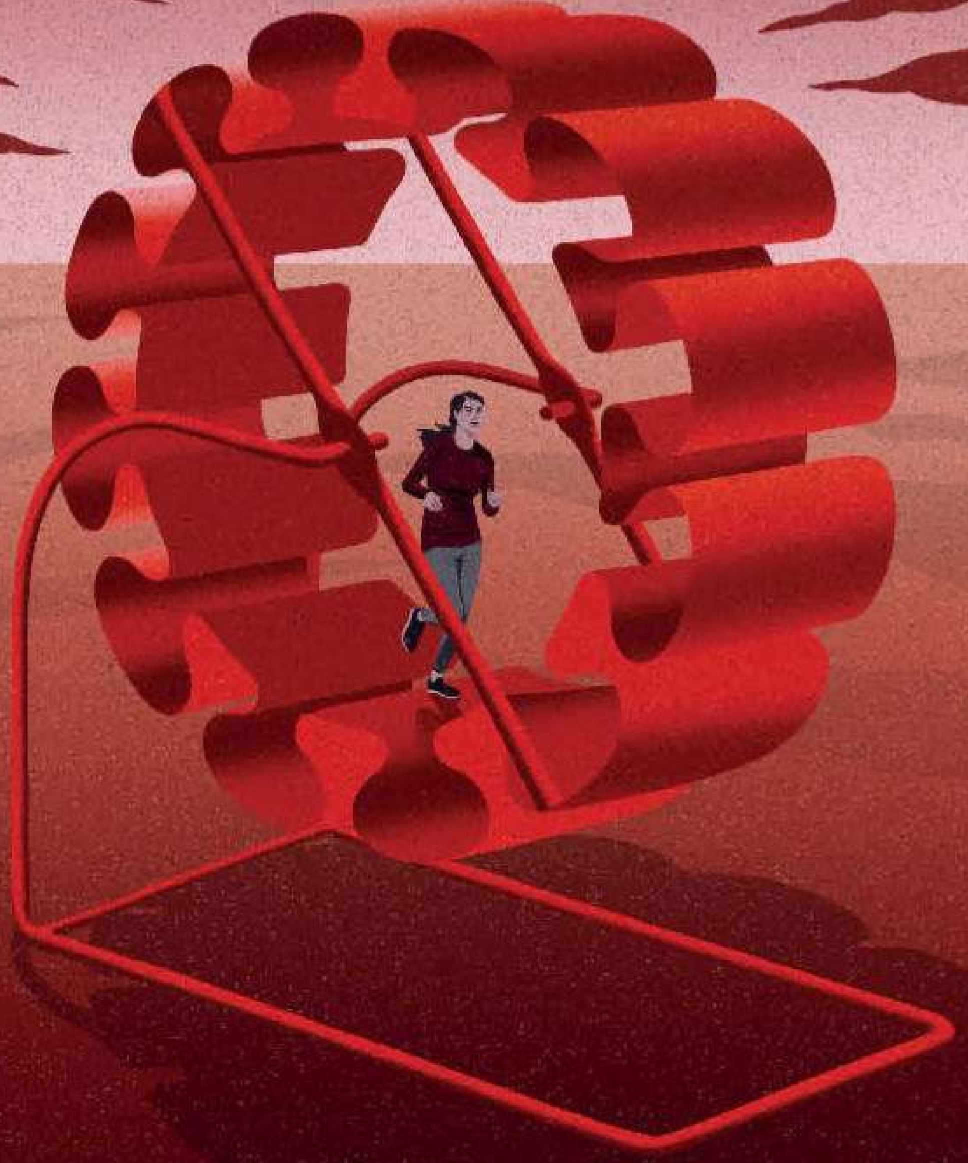
WEEKLY 8 January 2022

THE POWER OF PARADOX
What we learn when intuition and logic collide

WELCOME TO THE METAVERSE
The hype versus the reality

SPECIAL REPORT

COVID: WHAT'S NEXT?



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AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

Your Will can fund the rational response to health challenges that medical science provides.

> "As scientists, our duty is to secure the future of research for the generations that follow."
>
> Professor Fiona Watt, President of the Medical Research Foundation and Executive Chair of the Medical Research Council.

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.

Changing medicine today.
Changing lives tomorrow.
medicalresearchfoundation.org.uk

"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

But many of these scientists rely on the generosity and foresight of fellow members of the public – people like you, who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

Please consider this very special gift today.

Professor Nick Lemoine MD PhD FMedSci
Chair of the Medical Research Foundation

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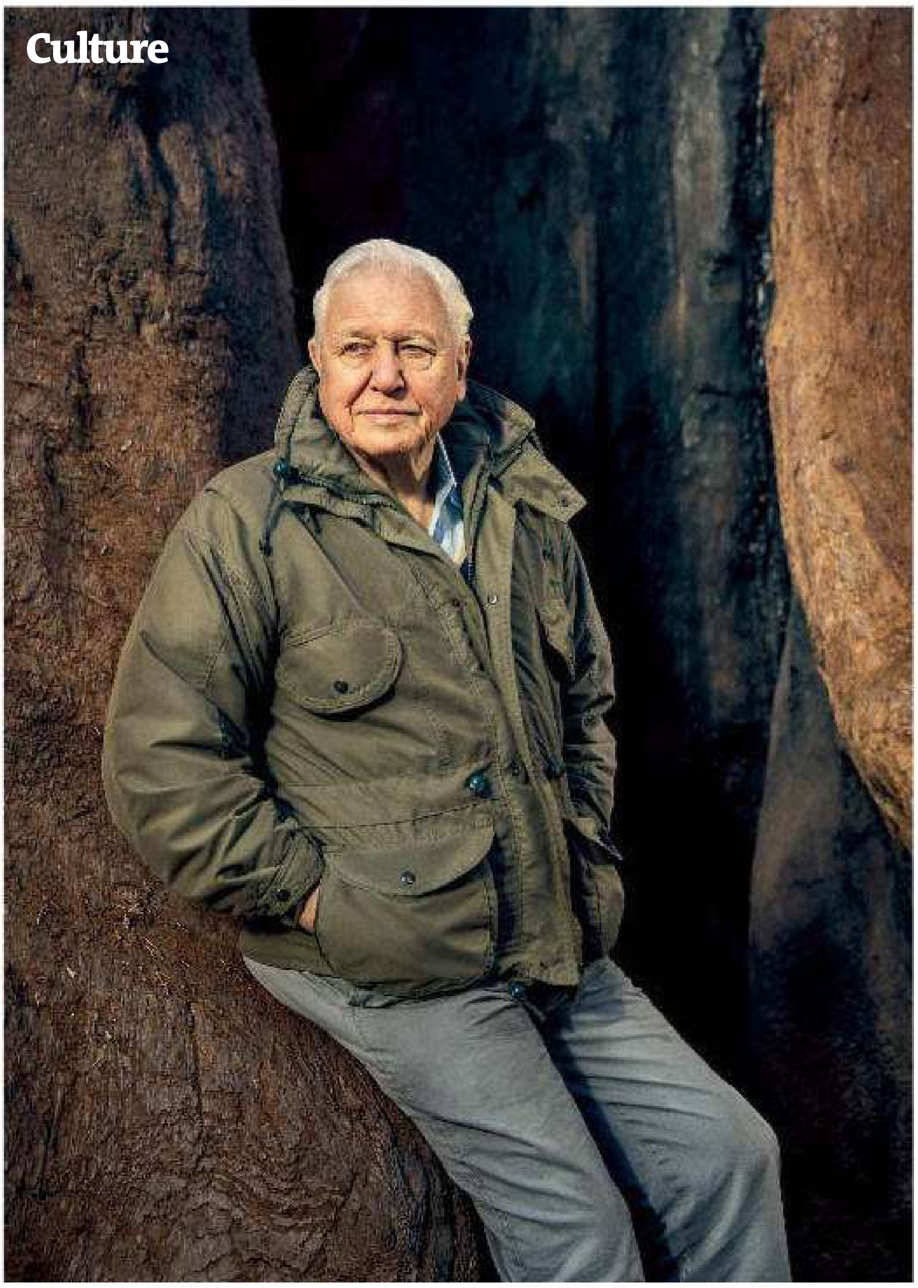

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Virtual events

Nutrition and mental health

Strange as it may sound, the bacteria that live in our guts have a crucial influence on our mental health. And since what we eat controls the balance of these microbes, the right dietary choices could potentially boost our mood and reduce anxiety. In this online talk, microbiome expert Ted Dinan explains how this happens and doles out some practical advice on eating yourself happy. Join us on 27 January from 6pm GMT (1pm EST).

Brain power

What does it mean to have a healthy, happy brain? In this virtual event, *New Scientist*'s head of features, Catherine de Lange, will unpack the latest understanding of how sleep, diet, exercise and our social lives are imperative for keeping our brains in good shape. Join us on 3 February from 6pm GMT (1pm EST). Tickets to these events and many more are available online now.

newscientist.com/ns-events

Online

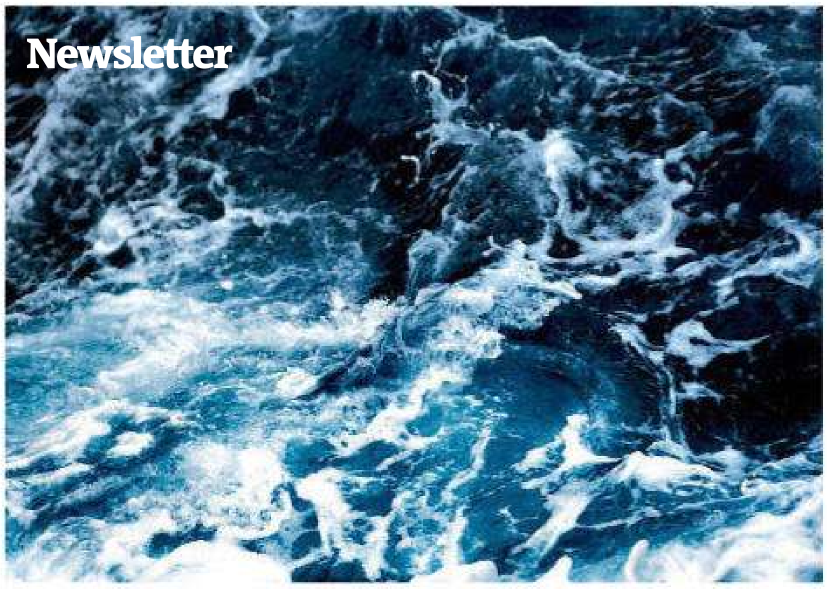
Covid-19 daily briefing

Stay on top of all the latest developments in the pandemic, from variants to vaccines, with our essential news round-up, updated each weekday. There are also links to our exclusive features and interviews.

newscientist.com/coronavirus-latest

DAVE STOCK

All-seeing AI Beth Singler says we give AI a god-like status



ALEXZAITSEV/SHUTTERSTOCK

Sea change A radical plan to suck carbon from the ocean, not the air

Video

Meet the AI anthropologist

Beth Singler studies how humans connect with artificial intelligence. She tells us that we are beginning to subtly credit AI with a godlike status, explains why that is problematic and discusses where our relationship with machines might go in the far future. Subscribe to our channel for more videos and explainers.

youtube.com/newscientist

Newsletter

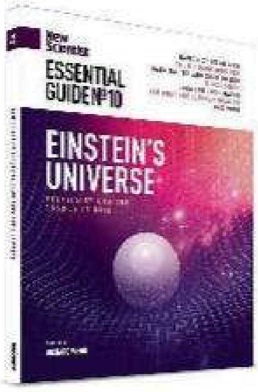
Fix the Planet

Get Adam Vaughan's weekly dispatch on climate science delivered free to your inbox. In a recent issue, he looks at some quirky new ideas for trapping carbon dioxide. One involves sucking CO_2 out of seawater, so that it can in turn soak up more of the greenhouse gas from the air.

newscientist.com/fix-the-planet

Newsletter

> **“The ocean already absorbs CO_2, but carbon-depleted seawater could absorb far more”**



Essential guide

How did the universe begin? What is it made of? Do black holes exist? Albert Einstein's space and time-warping theory of relativity has revolutionised our view of the cosmos over the past century. Find out how in the 10th *New Scientist Essential Guide*, available now.

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ATEM Mini Pro model shown.

Introducing ATEM Mini Pro

The compact television studio that lets you create presentation videos and live streams!

Blackmagic Design is a leader in video for the television industry, and now you can create your own streaming videos with ATEM Mini. Simply connect HDMI cameras, computers or even microphones. Then push the buttons on the panel to switch video sources just like a professional broadcaster! You can even add titles, picture in picture overlays and mix audio! Then live stream to Zoom, Skype or YouTube!

Create Training and Educational Videos

ATEM Mini's includes everything you need. All the buttons are positioned on the front panel so it's very easy to learn. There are 4 HDMI video inputs for connecting cameras and computers, plus a USB output that looks like a webcam so you can connect to Zoom or Skype. ATEM Software Control for Mac and PC is also included, which allows access to more advanced "broadcast" features!

Use Professional Video Effects

ATEM Mini is really a professional broadcast switcher used by television stations. This means it has professional effects such as a DVE for picture in picture effects commonly used for commentating over a computer slide show. There are titles for presenter names, wipe effects for transitioning between sources and a green screen keyer for replacing backgrounds with graphics.

Live Stream Training and Conferences

The ATEM Mini Pro model has a built in hardware streaming engine for live streaming via its ethernet connection. This means you can live stream to YouTube, Facebook and Teams in much better quality and with perfectly smooth motion. You can even connect a hard disk or flash storage to the USB connection and record your stream for upload later!

Monitor all Video Inputs!

With so many cameras, computers and effects, things can get busy fast! The ATEM Mini Pro model features a "multiview" that lets you see all cameras, titles and program, plus streaming and recording status all on a single TV or monitor. There are even tally indicators to show when a camera is on air! Only ATEM Mini is a true professional television studio in a small compact design!

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Into year three

It isn't over yet, but the future of the pandemic is in our hands

WHAT a difference a month makes. In November, when we commissioned our retrospective on the amazing scientific endeavour that has characterised the covid-19 pandemic over the past two years (see page 10), life in certain parts of the planet was inching its way back to some semblance of normality. Then came the curveball, omicron.

No one should have been surprised. A variant such as this was predictable, as World Health Organization director general Tedros Adhanom Ghebreyesus (interviewed on page 15) has pointed out. Countries can expect more of the same in the year to come. As long as cases remain high around the world, other variants will follow. And while recent analyses suggest that omicron is more transmissible but less severe than delta (people with omicron seem about half as likely to be hospitalised compared with those infected with delta), future variants may be more dangerous.

So we should expect more twists and turns in 2022 (see page 14). In many ways, the progress of the past two years has prepared us for them. We have 23 approved covid-19 vaccines that offer significant protection against severe disease. We have new antivirals that can prevent hospitalisation in those who are most at risk, and a pipeline of other treatments on the way.

> "The choices we all make each day can still help steer the direction of the pandemic"

That doesn't mean it is time to "learn to live with" the virus, a phrase commonly used to suggest ditching all restrictions and protective measures. The year will be long and people's behaviour will make a big difference to how things play out. With omicron spreading fast, some countries, including the UK, are seeing higher numbers of new cases than they have since the start of the pandemic. Each one gives the virus a chance to mutate.

Yet again, the new variant is a reminder of the need for global vaccine equity if the course of the pandemic is to be truly changed as we enter its third year. Whatever curveballs lie ahead, the choices we all make each day – with regards to social distancing, mask wearing, vaccination and good ventilation – will also help steer the pandemic in the right direction in the year to come. ▮

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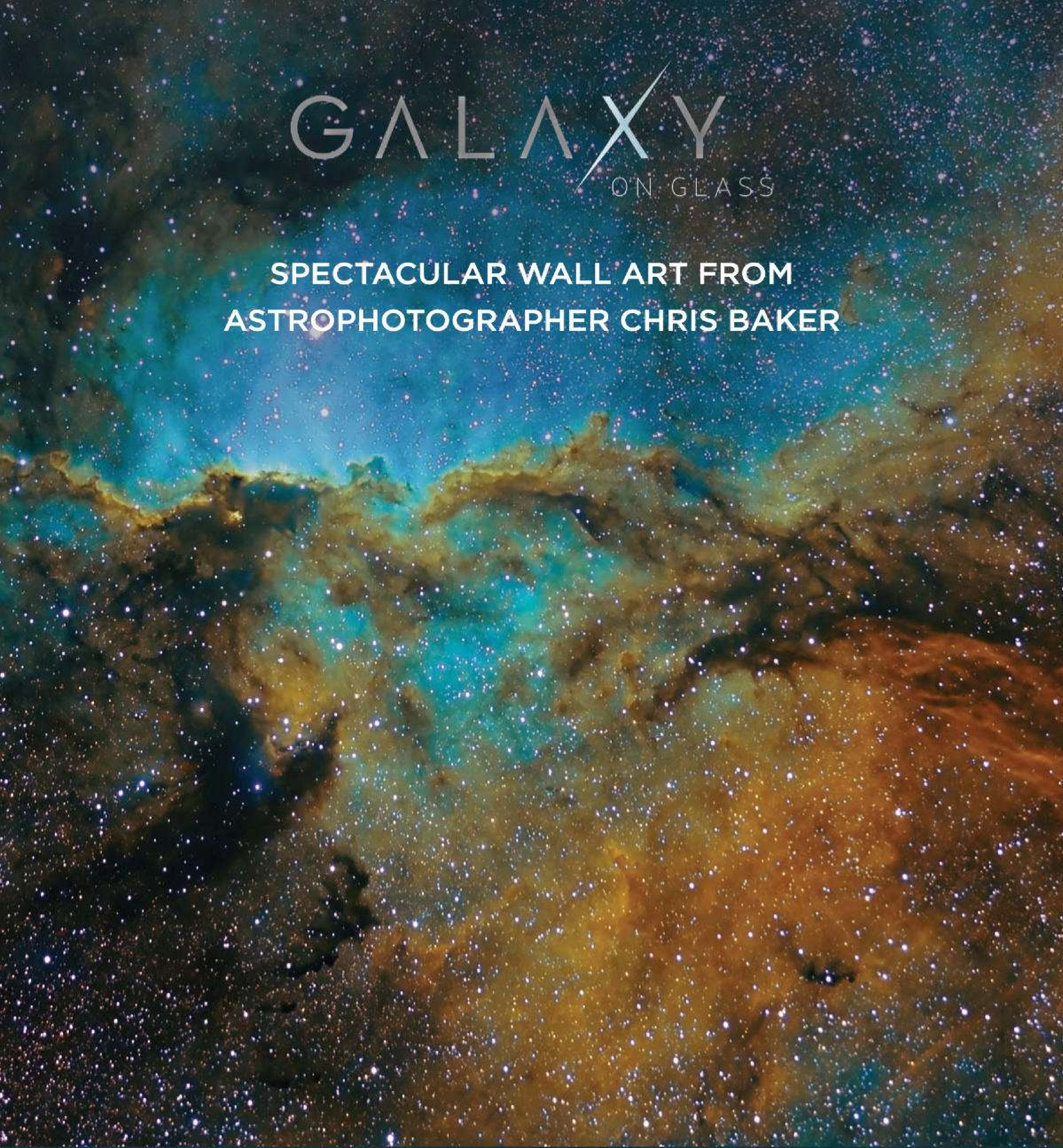

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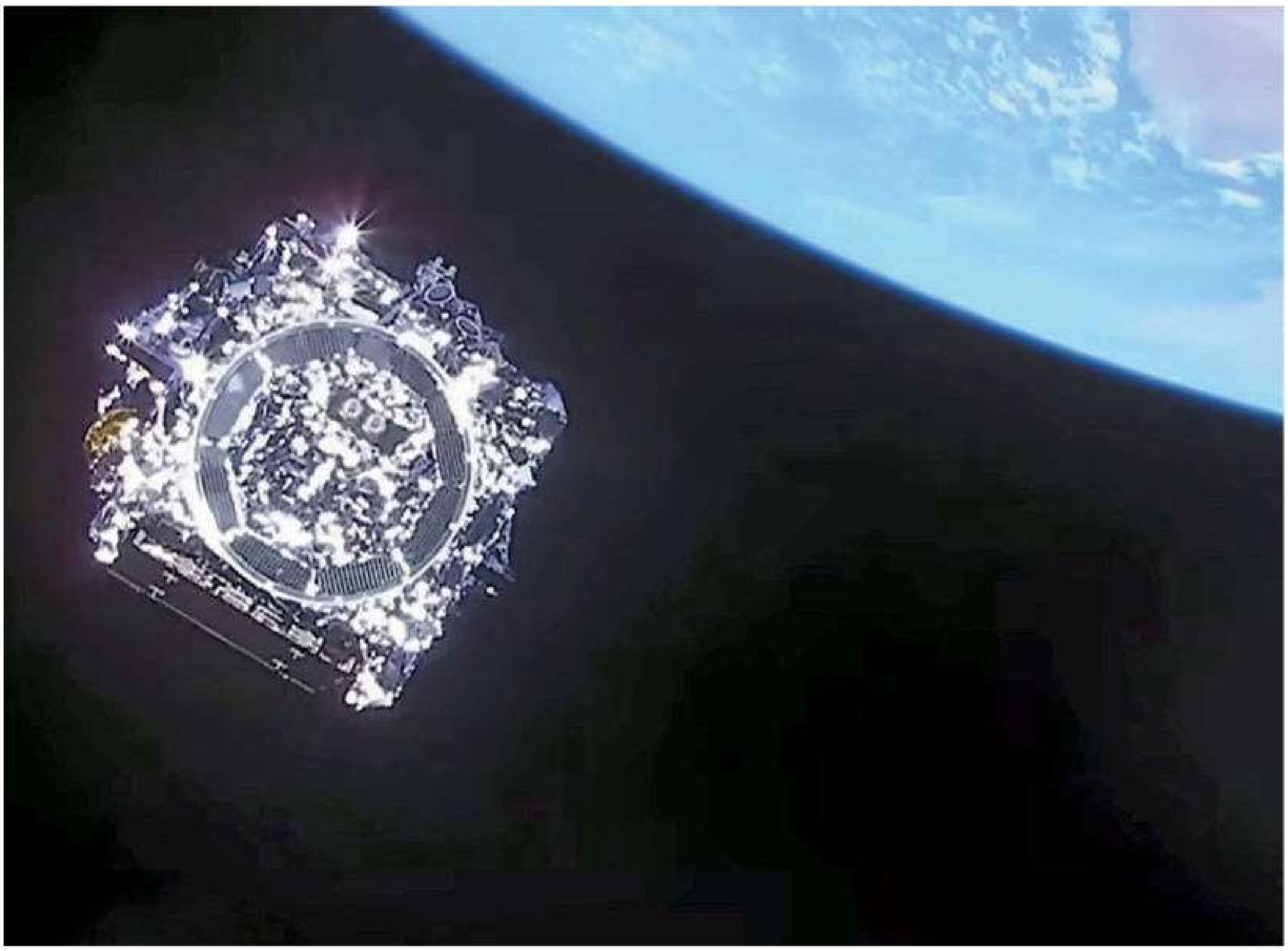


The James Webb Space Telescope seen from the Ariane 5 rocket it launched on

ARIANESPACE, ESA, NASA, CSA, CNES

Space exploration

The Webb takes shape

The James Webb Space Telescope is opening up as it gets ready to reveal the mysteries of the early universe, reports **Alex Wilkins**

AFTER a nail-biting launch on Christmas Day, the James Webb Space Telescope (JWST) has begun its mission to image the birth of the universe.

The JWST blasted off from French Guiana at 12:20 GMT on 25 December on top of an Ariane 5 rocket, folded into a compact cuboid. About 27 minutes later, it separated from the rocket and deployed its solar array, which powers its propulsion and communication systems, as well as scientific instruments.

Its next big manoeuvres were two course-correction burns, firing rocket thrusters to nudge the space telescope towards its correct orbit around the sun, at a gravitationally stable location called L2 about 1.5 million kilometres from Earth.

The two burns used less fuel than anticipated thanks to the accuracy of the Ariane 5 rocket, which means the JWST will have enough propellant to last "significantly" longer than its expected 10-year operation time, according to NASA engineers. Unlike its predecessor, the Hubble Space Telescope, the JWST will be too far away to service, so any leftover fuel is a bonus.

On 3 January, JWST operators began the spacecraft's most critical manoeuvre: the unfolding and tensioning of its sunshield, which protects the telescope's sensitive instruments from the sun's powerful radiation.

The shield is made of five layers of a lightweight thermal material called Kapton and is as wide as a tennis court. Deploying it is a multistep process involving more than 140 release mechanisms.

If these don't execute correctly, the entire mission could be in danger, but NASA engineers are confident of success after their numerous rehearsals on the ground.

"I don't expect any drama," said JWST project manager Bill Ochs during a press conference on 3 January. "The best thing for operations is 'boring'. And that's what we anticipate over the next three days – to be boring."

"The best thing for operations is 'boring'. And that's what we anticipate over the next three days"

As *New Scientist* went to press, the first three layers of the shield had been deployed and tightened and the rest of it was expected to be tensioned by the end of 4 January. However, the sequence could take longer depending on the data that the JWST's engineers receive on the ground.

As well as planned manoeuvres, NASA engineers have had to adapt to changing conditions aboard the JWST, like fine-tuning its power systems and accounting for higher than expected temperatures inside the sunshield's motors due to incident sunlight.

"We've had a week to see how the observatory actually behaves in space. It's not uncommon to learn certain characteristics of your spacecraft once you're in flight," said Mike Menzel at NASA's Goddard Space Flight Center in a statement.

Once the sunshield is in place, the next big task is the deployment of the telescope's mirrors. First, a secondary reflector will be extended in front of the primary mirrors on 7 January, and then the 6.5-metre-wide primary mirrors will be unfolded on 8 and 9 January.

After the 18 hexagonal, gold-plated beryllium mirrors are fully deployed, the JWST will continue on to L2 by the end of January, if all goes according to plan. The telescope will then have its instruments and systems tweaked for an extra five months before being ready to image the primordial universe.

The JWST will view the cosmos in infrared light, and should be able to see objects that are between 10 and 100 times fainter than those pictured by Hubble, and in detail 10 times as precise. These include the first stars and galaxies, formed hundreds of millions of years after the big bang, and potentially habitable exoplanets, which it will study by investigating their atmospheres.

Covid-19

Two years of the coronavirus

How has our understanding of the virus changed since it went global in 2020 and where does that leave us? **Helen Thomson** reports

ON 31 December 2019, Chinese authorities informed the World Health Organization (WHO) about a cluster of "viral pneumonia" cases of unknown cause in the city of Wuhan. Two years later, the coronavirus now known as SARS-CoV-2 has resulted in at least 5.4 million deaths. As the world awaits the full impact of the new variant omicron, *New Scientist* looks back at the phenomenal scientific endeavour across the pandemic, and at how much we now know about the virus and how to fight it.

Where did covid-19 come from?

In March 2021, a group tasked by the WHO to investigate covid-19's origins concluded that SARS-CoV-2 is most likely to be an animal virus that moved into humans through contact with an animal host, either at the Huanan Seafood Wholesale Market, a live animal market in Wuhan, or at another step in the trade of wildlife.

"From early on in the pandemic, experts disagreed about how covid-19 was spread"

The WHO group hedged its bets because the first person reported to have become ill with covid-19 on 8 December 2019 had no link with the market. A more recent analysis, however, suggests that this individual actually developed symptoms on 16 December, and only visited a hospital on 8 December for dental problems.

This means the earliest known case may indeed have had ties to the market: a seafood vendor who became sick on 11 December. A third of the 168 people later identified as having had the virus in December 2019 had connections to the market.

A new hospital was rapidly built in Wuhan, China, in early 2020

The mounting evidence for a market origin weakens the case for a lab leak, a premise that couldn't be ruled out by an investigation commissioned by US president Joe Biden in 2021. Since these investigations, coronaviruses that are the closest match yet found to SARS-CoV-2 have been discovered in bats in Laos, says Marion Koopmans at Erasmus University Medical Centre in the Netherlands, who was part of the WHO's investigation team. Certain features of these wild viruses were the same as those that some researchers claimed could only have arisen during "gain of function" tests in a lab, in which an organism is genetically altered to enhance certain characteristics.

A June 2021 paper in *Scientific Reports* adds further support to the market origins story. The authors were serendipitously surveying markets in the Wuhan area that were selling wild animals for food or pets between May 2017 and November 2019. They discovered many animal welfare and exploitation issues with "considerable implications for food hygiene". The animals traded are capable of hosting a wide range of infectious diseases, they say.

Some early covid-19 cases were linked to an area of Huanan market where wild animals such as raccoon dogs were kept. These animals can be infected and display few symptoms, boosting the idea that animals in the market acted as an intermediate reservoir for the virus, says Koopmans.

In response to covid-19, China temporarily prohibited all wildlife trade until the pandemic concludes and permanently banned the eating and trading of non-livestock animals for food.

How does the coronavirus spread?

Back in January 2020, researchers urgently needed to understand the nature of the virus and how it was spreading. On 3 January, Yong-Zhen Zhang at Fudan University in Shanghai, China, was given a box containing swabs from people with the mysterious pneumonia sweeping Wuhan. By 5 January, having worked two nights straight, Zhang's team had sequenced the virus and identified it as a coronavirus. That same day, Zhang uploaded the genome to the US National Center for Biotechnology Information. By comparison, in 2003, scientists took two months to identify the cause of an international outbreak of a new disease, SARS, as a coronavirus.

It soon became clear that SARS-CoV-2 spread easily and could cause severe disease, particularly in older age groups or in those with underlying health issues. By the end of February, its death count had surpassed those caused by the coronaviruses responsible for the SARS outbreak and MERS, a disease that emerged in 2012.

The WHO declared the covid-19 outbreak a pandemic on 11 March 2020. Working out how to minimise transmission was key, but from early on, there was

STR/AFP VIA GETTY IMAGES

disagreement among experts. At first, the focus was on surface transmission – infected people contaminating surfaces that were then touched by others. Swabs from hospitals found the virus lurking everywhere, from stethoscopes to reading glasses. Sales of hand sanitiser soared.

Other researchers concentrated on transmission via large droplets spread as an infected person coughs or sneezes near others. Droplets are heavy and fall from the air within seconds, rarely travelling more than 2 metres.

Social distancing and face coverings were widely implemented as a way to help prevent this type of spread. But rigorous evidence on the effectiveness of face coverings was slow to appear and often contested. The WHO initially only recommended them for people who were actively coughing or caring for those with covid-19.

Today, we know that all face coverings help cut the risk of catching and transmitting the virus to a certain extent.

Then, there is the issue of aerosols. These tiny particles hang in the air and so can travel further than 2 metres, but many researchers initially disregarded this route of spread. The WHO stated at a press conference on 27 March 2020 that “transmission of covid-19 is through droplets, it is not airborne”.

This is because doctors have traditionally assumed that respiratory diseases, like tuberculosis and influenza, are spread mainly by droplets – “coughs and sneezes spread diseases”, says Trisha Greenhalgh at the University of Oxford. “It’s a mindset that’s deeply ingrained in the infectious disease community.” But more recent research has shown that both TB and flu can be spread via aerosols, upending conventional wisdom.

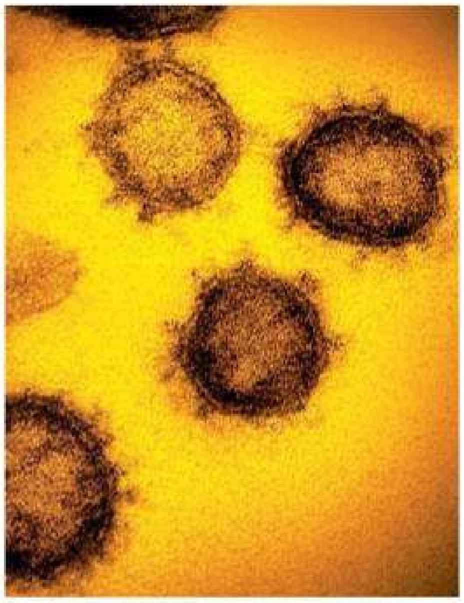
The tide began to turn in July 2020, when 239 scientists from 32 countries published evidence that SARS-CoV-2 was airborne, appealing to the WHO and others to acknowledge its impact. However, it wasn’t until May 2021 that the WHO and the US Centers for Disease Control and Prevention changed their guidance, stating that aerosols are the primary route for transmitting the virus, mainly between people in close proximity with each other, and typically 1 to 2 metres apart, or in poorly ventilated or crowded indoor environments.

Subsequent research has shown that surface transmission is likely to be a factor in the spread of the virus, but not a primary means. Good ventilation is now seen as a vital control measure.

All of this has left some scientists urging a paradigm shift in how we combat respiratory infection. In a call for action published in *Science* in May 2021, a group of more than 30 scientists and doctors pointed to the great disparity in the way in which we address different sources of environmental infection. While governments have long invested in food safety, sanitation and clean drinking water, the group argued that airborne infections haven’t been targeted strongly enough through changes to regulations, standards and building design that could help prevent their transmission.

How has the virus evolved?

As soon as the coronavirus started spreading, it also began to mutate, leading to new variants. “Omicron should not surprise anyone, it is what viruses do,” said Tedros Adhanom Ghebreyesus, director general of the WHO, at a press conference in December 2021. “It’s what this virus will continue to do as long as we allow it to continue to spread.”



NATIONAL INSTITUTES OF HEALTH-RML/SPL

An electron micrograph of the SARS-CoV-2 virus that causes covid-19

Each time a virus replicates, it has a chance of mutating. Some mutations make it better at moving through a population. The first new variant to spread widely was alpha, which was sequenced in September 2020 and is about 50 per cent more transmissible than earlier variants. It was first identified in the UK and research suggests that it may have evolved in someone with a weakened immune system. This meant they couldn’t wipe out the virus, encouraging it to evolve and mutate.

“In hospitals, the virus was found lurking everywhere, from stethoscopes to reading glasses”

Next came beta, which was first spotted in South Africa and was first sequenced in October 2020. Among its mutations is one that alters the shape of a key protein, helping it to evade antibodies that are effective against other variants. Recent work suggests it spread quickly because it is 20 per cent better than previous variants at evading the immune response in previously infected people.

In late 2020, another variant, gamma, emerged and caused a surge of cases in Manaus, Brazil. Here, it was estimated that 75 per cent of the population had already been infected with SARS-CoV-2. The new variant had a mutation allowing the virus’s spike protein to bind more easily to cells, making it more infectious. This protein is the part of the virus that recognises host cells, and is the main target of our immune response. Another mutation helped it evade antibodies from past infections.

Then delta swept the world. The variant was sequenced in October 2020 and first detected in India, where it caused a huge wave of infections. At least 50 per cent more transmissible than alpha, delta outcompeted all other variants over the course of 2021, becoming the most common one in the world. Vaccines are still effective against it, but are around 15 per cent worse at preventing infection by delta than by alpha.

Omicron, which emerged in November 2021, has the highest number of mutations so far seen in the spike protein, and we don't yet know their full impact. You can eyeball the mutations in order to work out what effect they might have, says Danny Altmann at Imperial College London, "but many are new".

Omicron spread rapidly in South Africa, where a large majority of the population has previously been infected but only about 25 per cent are fully vaccinated.

By 18 December 2021, a total of 89 countries had detected the presence of omicron. The variant appears to spread much faster than others. A December study of data from South Africa suggested that omicron is 4.2 times more transmissible in its early stages than delta, and there is some evidence that it may multiply in our airways 70 times faster.

The variant also seems to exhibit "immune escape", to some extent evading the immune responses of people who have already had covid-19 or been vaccinated. Lab studies by Pfizer suggest that three doses of the vaccine it developed with BioNTech offer significant protection against infection from omicron, but two doses don't.

Uğur Şahin, CEO of BioNTech, said in a press statement that a component of our immune system, called memory T-cells, generated by the vaccine, may prevent severe disease in those who haven't had three shots.

50%

Increased transmissibility of the alpha variant

20%

How much better beta was at evading the immune system in previously infected people

70%

Possible decrease in risk of hospital visits from omicron, compared with delta

The variant's ability to infect the double-vaccinated prompted the UK to open up its booster programme to all adults in December. Infection numbers in the UK have since hit record highs, but there has been some good news, as preliminary analyses of data from England suggested that infection with omicron may be around 20 to 70 per cent less likely to result in a hospital visit. In people who haven't yet caught covid-19 or been vaccinated, hospitalisation with omicron appears to be about 11 per cent less likely than with delta. However, this is unlikely to be enough to counteract the variant's extreme transmissibility, and health systems worldwide are bracing for surges in hospital admissions.

What do we still not know?

Two years on, several key questions about the virus are yet to be resolved, including the virus's origins. Although evidence suggests it began in a market in China and that it derives from a bat coronavirus, it isn't clear how it spread to humans.

We don't know the dose of SARS-CoV-2 needed to transmit infection. To work this out, several human challenge trials are under way, in which volunteers are given varying viral doses in controlled conditions.

We also need to identify the level of antibodies needed to prevent infection, which is helpful for assessing how effective vaccines are and also for rapidly deciding whether they need to be changed. Researchers met in December 2021 to discuss data on antibodies for all the variants of concern, to reach an agreement on what antibody levels are required to protect people against severe disease. Results are forthcoming.

We don't know what future variants might be called, once we have run out of Greek letters. The World Health Organization is considering using lesser-known constellations next, says Maria Van Kerkhove at the WHO.

And finally, we don't know how dangerous future variants may be.

The closed Huanan Seafood Wholesale Market in January 2020

NOEL CELIS/AFP VIA GETTY IMAGES

How good are the vaccines?

The major success story of the pandemic has been how fast vaccines were created. Thanks to years of research following the SARS and MERS outbreaks, researchers had a good idea of what aspects of SARS-CoV-2 to target. The pandemic also coincided with the maturation of mRNA vaccine technology.

Traditional vaccines tend to contain weakened or inactivated virus that the body learns to recognise so it is ready to fight the virus when next encountered. The new Pfizer/BioNTech and Moderna vaccines introduce an mRNA sequence that tells the body to make a harmless part of the coronavirus's spike protein, which triggers an immune response. These vaccines can be developed faster and more cheaply than traditional ones.

For vaccines of all types, money was pumped into trials so multiple studies could be run at the same time, and cash was given to manufacturers to increase production capacities.

We now have 23 covid-19 vaccines in use, and around 135 others in various stages of human trials. There have, of course, been hurdles. The Oxford/AstraZeneca

Daily coronavirus news round-up
Online every weekday at 12pm GMT
newscientist.com/coronavirus-latest

jab was linked to rare blood clotting events, which led to some countries restricting its use.

Still, the vaccine programme has worked so well in high-income nations that covid-19 was referred to as a disease of the unvaccinated by Andrew Pollard, director of the Oxford Vaccine Group at the University of Oxford. He wrote in *The Guardian* in November 2021 that the "ongoing horror" of people with covid-19 fighting for breath in intensive care units across Britain "is now largely restricted to unvaccinated people".

While we wait to see omicron's impact on hospitalisations and deaths, the good news is that if it, or any other variant, undermines the current vaccine programme, scientists are prepared. Pfizer CEO Albert Bourla has said his company could make an updated vaccine in less than 100 days. Others are working on variant-specific and multi-variant vaccines.

What treatments do we have?

Vaccines aren't our only tool against the virus. Steroids, including dexamethasone, the first drug proven to save lives from covid-19, have been used by medics from the beginning of the pandemic. Doctors reasoned that steroids would help reduce the impact of severe disease by preventing the immune system from going into overdrive and damaging organs. That turned out to be true – a discovery that was unprecedented in its speed, thanks to collaboration across seven clinical trials in 12 countries, coordinated by the WHO.

Three monoclonal antibodies, which are manufactured versions of antibodies that attach to the virus's spike protein and make it harder for it to enter human cells, have been given emergency approval by the US Food and Drug Administration (FDA).

The drugs showed promise in reducing hospitalisation in infected people at high risk of more severe disease. They also decreased the spread of disease to other people in the household when taken prophylactically. However, there are suggestions from recent data that some monoclonal antibody drugs may not be effective against omicron.

SIA KAMBOU/AFP VIA GETTY IMAGES

JEROME DELAY/AP/SHUTTERSTOCK

ZOONAR/WOLFGANG FILSER/ALAMY

From top: vaccine arrives in the Ivory Coast; researchers in South Africa work on omicron; vaccine vials; queues for booster shots in London

ROB PINNEY/GETTY IMAGES

"Scientists are prepared if omicron, or another variant, undermines the vaccine programme"

Monoclonal antibodies are also expensive and hard to give outside a hospital setting. Oral antivirals that can be taken at home may be a better option. One, a drug made by Pfizer called Paxlovid, has shown very promising results. When taken for five days shortly after symptoms start, the drug cut hospital admissions by 89 per cent in adults at high risk of severe illness. The drug appears to work well against omicron, and was given emergency approval by the FDA on 22 December. President Biden has already ordered enough pills to treat 10 million people.

Another antiviral, molnupiravir from Merck, appears to reduce the risk of hospitalisation or death by about 30 per cent in at-risk people with mild to moderate covid-19. The UK approved this drug in November 2021.

Other treatments are in human trials. For instance, the cheap oral antidepressant fluvoxamine has shown strong evidence of preventing covid-19 progressing from a mild case to a severe one in those at serious risk. ▮

Covid-19

What will happen this year?

Expect more viral evolution but reduced mortality, and some continuing restrictions, report **Helen Thomson, Clare Wilson** and **Michael Le Page**

WHILE the pandemic is unlikely to fully end in 2022, we can hope to see some positive changes: more vaccine coverage, improved treatments and reduced mortality. But mitigation measures, such as mask wearing and social distancing, will remain crucial for controlling outbreaks and restricting the evolution of the SARS-CoV-2 coronavirus.

Maria Van Kerkhove, the technical lead on covid-19 at the World Health Organization (WHO), dislikes the phrase "learning to live with the virus". She says: "I don't think we should learn to live with it. There are lots of things we can be doing to stop the virus from spreading. No level of death from covid-19 is acceptable to me." The next year will unfold how we allow it to, she says. "How we use the vaccine going forward among those most at risk will be critical to what happens."

A crucial issue will be vaccine equity. By late December, more than 8 billion doses had been given globally, but only 8.1 per cent of people in low-income nations had received at least one jab. "Global leaders haven't utilised the vaccine as they should have," says Van Kerkhove. "If we'd used 8 billion doses differently, we'd be seeing a very different epidemiological situation right now."

"It won't be forever. That is something we can say for certain – the pandemic will end"

In December, WHO member states agreed to draw up a treaty by 2024 that will set out new international rules on preparing for, preventing and responding to pandemics. Forthcoming negotiations are expected to partly tackle the inequality of vaccine provision. "Just as countries have come together against tobacco and climate change, health security is too important to be left to chance or friendly agreements," says Tedros Adhanom Ghebreyesus, the WHO's director general (see "The actions that will change the pandemic", right).

SEBASTIEN SALOM-GOMIS/AFP VIA GETTY IMAGES

Theme park visitors show their covid passes in France, July 2021

Bary Pradelski at the French National Centre for Scientific Research says that, for Europe, overcoming vaccine hesitancy is key. He says covid certificates have proven an effective incentive in many countries, but they need to be non-discriminatory. "It is unacceptable if vaccines that are deemed effective by the WHO are not eligible for covid certification in some regions, as is the case in the EU," he says.

Vaccination efforts, including the development of updated jabs to tackle new variants, should continue to lessen the impact of covid-19 in 2022. "I expect to continue to see a significant reduction in mortality in those who are vaccinated," says Van Kerkhove. "We hope to significantly reduce the severe end of the covid spectrum."

Progress with treatments against the disease adds to this hope. "Vaccines will remain the cornerstone of our fight against covid-19, but with various new variants coming along, the oral [treatments] may well have a very important part to play in the next year," says Philip Evans at the UK National Institute for Health Research.

The UK, for example, is beginning to use antiviral drugs and artificial antibodies in those with an elevated covid-19 risk. People who are most vulnerable to infection – such as those with cancer, Down's syndrome or weak immune systems – are eligible to receive the intravenous drug sotrovimab, a monoclonal antibody that is designed to block the virus, if they test positive for covid-19.

RAMON ANDRADE 3DCIENCIA/SPL

An illustration of the antiviral drug molnupiravir

Specialist hospital clinics in the UK are also now offering the oral antiviral molnupiravir to people who aren't classed as extremely vulnerable, but who are still at higher risk, such as those aged 50 and up or people with conditions like diabetes or severe asthma, as part of a large trial.

Taken early enough, the drug can prevent hospital admission, but molnupiravir has potential downsides. It works by introducing mutations in the virus's genetic material, so isn't suitable for use during pregnancy, for example. There is also concern that these mutations could lead to new variants or drug resistance. David Lowe at University College London, who is involved in the trial, says mutations aren't a big concern. "Once you've given [the drug] for a few days, the level of infectious virus is so low that you can't even culture it," he says. "But it is something that we need to keep an eye on."

The start of this year will be dominated by the omicron variant, which has around 50 mutations compared with the original virus, of which 30 are in its outer spike protein that is targeted by vaccines. The extensive changes in this protein greatly reduce the effectiveness of antibodies against the variant.

It is possible that this variant evolved in an individual with HIV who caught covid-19 and was unable to shake off the virus for some time. There is no direct evidence that this is what happened, but the researchers who discovered omicron have called for efforts to tackle HIV to be stepped up. This underlines how important it will be to rein in infections, especially among people with weak immune systems, to reduce the potential for new variants to evolve.

But new variants could emerge in other ways too. Another scenario put forward to explain omicron's origin is that the virus infected animals of some kind, acquired lots of mutations as it spread among them and then jumped back to people. Some of the mutations in omicron's spike protein are the same as those seen in SARS-CoV-2 viruses that have adapted to spreading in rodents like mice, although this could just be a coincidence.

The repeated discovery of SARS-CoV-2 in wild animals, for instance in white-tailed deer in the US, concerns Marion Koopmans at Erasmus University Medical Centre in the Netherlands, who says 2022 will be a "rough period". The widespread infection of these deer in the US means there is a risk that other animals will get infected and that new variants will emerge and be passed back to humans. "It is something that we need to actively and aggressively monitor, in order to avoid creating new reservoirs for the virus," she says.

It is also possible that variants could combine with each other or other coronaviruses. The virus will evolve because we aren't doing enough to stop transmission, says Van Kerkhove. "I'm not talking about lockdowns, but social distancing, mask wearing, working from home, improving ventilation," she says. "We need to open up societies carefully without abandoning these public health measures."

Eventually, she believes covid-19 will become seasonal, with periodic spikes in populations with lower levels of immunity. But this won't happen any time soon due to the virus thriving in all parts of the world, she says.

8.1%

of people in low-income countries have received a vaccine dose

Other researchers are more optimistic. "In 2022, we will move more to the endemic phase of SARS-CoV-2 infection, where we continue to learn to live with the virus," says Elizabeth McNally at Northwestern University in Chicago, Illinois.

However, Van Kerkhove remains positive. "It won't be forever, we will get through this. That is something we can say for certain – the pandemic will end."

When, though, is down to our actions, says Tedros. "The virus has demonstrated that it will not simply disappear. How many more lives and livelihoods it takes is up to us," he says. "Ending the pandemic is not a matter of chance, it is a matter of choice." ▮

Interview

The actions that will change the pandemic

World Health Organization head **Tedros Adhanom Ghebreyesus** explains what it will take to bring the pandemic under control

To change the course of the covid-19 pandemic, the international community must demonstrate a true commitment to urgent action and equity across all fronts of health.

To succeed, it will mean achieving several essential objectives. It will mean sharing what is needed to save lives now, from vaccines, diagnostics and treatments for the most vulnerable to PPE for health workers.

In particular, it will mean reaching the target of vaccinating 70 per cent of people in all countries by the middle of 2022, through swapping doses with countries in need, dose sharing and scaling up production through technology transfer and waiving intellectual property provisions on vaccine patents.

Hand in hand with vaccine equity, countries will need to continue using tailored public health and social measures, including mask wearing, physical distancing, avoiding crowded places, practising hand and respiratory hygiene, contact tracing and quarantine.

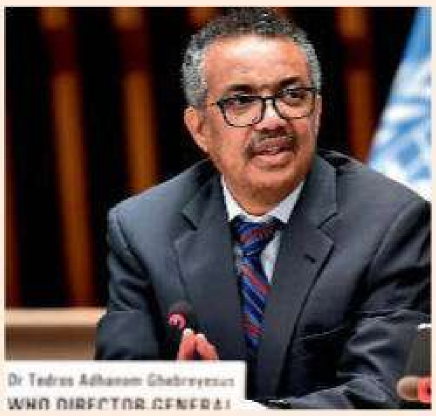
It will require enhanced surveillance, testing, sequencing and reporting of variants by all countries, without fear of punitive measures (such as blanket travel bans).

It will require well-managed clinical pathways from primary to intensive care, ensuring the right patient gets the right care at the right time, and that the health workforce is well supported and protected while doing their life-saving work. It will require intensified and targeted risk communication, community engagement, empowerment and support, addressing public concerns and building trust.

Beyond 2022, it will mean working together to build a binding global accord to deliver the governance, financing, systems and tools to prevent and respond to pandemics and protect future generations.

Above all, it will mean ensuring health for all by investing in universal health coverage, with primary healthcare as its foundation.

Interview by Helen Thomson



Profile

Tedros Adhanom Ghebreyesus is director general of the World Health Organization

REUTERS/ALAMY

Botany

'Near impossible' plant-growing technique could revolutionise farming

Alex Wilkins

A NEW method for grafting plants could increase production and eliminate diseases for some of the world's most imperilled crops, such as bananas and date palms.

Grafting, where the root of one plant is attached to the shoot of another, has been used in agriculture for thousands of years to improve the growth of plants such as apples and citrus trees and to eradicate diseases. But this technique wasn't thought to work for a major group of plants: the monocotyledons (or monocots). This category includes all grasses like wheat and oats, as well as other high-value crops like bananas and date palms. These species lack a tissue called vascular cambium, which helps grafts heal and fuse in many other plants.

Now, Julian Hibberd at the University of Cambridge and his colleagues have found an approach that allows monocots to be grafted. They extracted a form of embryonic tissue from inside a monocot plant seed and applied it to the potential graft site between two monocot specimens belonging to the same species – for instance, wheat.

JULIAN HIBBERD

A graft point between two date palms

The tissue stimulated growth and fused the two plant halves together. The researchers used fluorescent dyes to verify that the root and shoots had joined and could transport liquids and nutrients up and down the stem (*Nature*, doi.org/g94p).

"I have written on the record that I thought it was near impossible. So, as a science breakthrough, it's pretty amazing," says Colin Turnbull at Imperial College London.

The method appeared to work on a wide range of monocot plant families, including important crops such as pineapple, banana, onion, tequila agave, oil palm and date palm. The researchers' preliminary studies in the lab also suggest that the grafting can work between species – they grafted a wheat shoot to disease-resistant oat roots. This may protect the wheat from soil-borne disease, although it is unclear whether this protection would be feasible in the real world.

Hibberd, who worked on the research after a proposal from his colleague Greg Reeves, was initially hesitant. "Everyone said you can't do it, so I didn't want [Reeves] to dedicate a PhD to trying something that everyone says you can't do," says Hibberd. "It's a beautiful thing. It's science at its best, where you find something out even though everyone says it's not possible, and he proved me wrong."

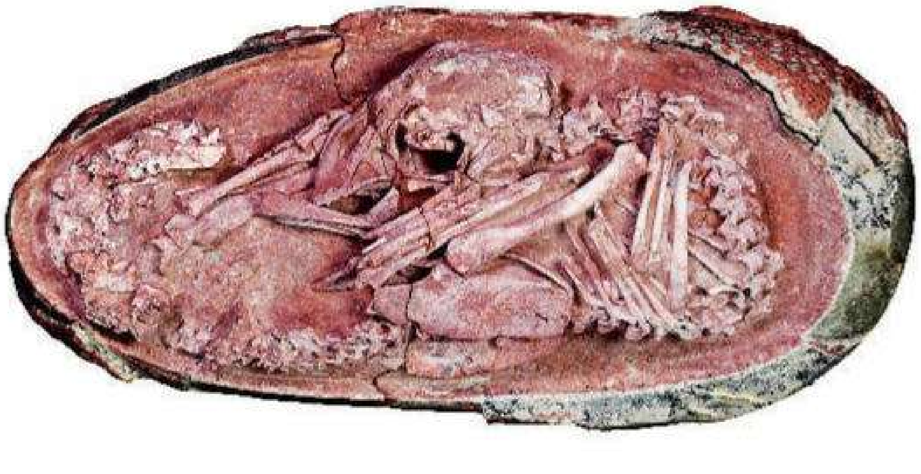
The technique could be especially useful for combating disease in vulnerable species like the Cavendish banana, which forms the vast majority of the world's supply of the fruit. Unable to proliferate sexually, the Cavendish banana is only reproducible by cloning, meaning the crop is highly genetically uniform and so vulnerable to threats like Panama disease, which is caused by a soil-borne fungus.

"It's science at its best, when you find something out even though everyone says it's not possible"

By grafting more disease-resistant stems (or rootstocks) with the banana plant, the Cavendish banana could avoid Panama disease. ▮

Palaeontology

Fossilised dinosaur embryo exquisitely preserved in its egg



The fossilised oviraptorid dinosaur embryo curled up in its egg

XING ET AL., 2021

A FOSSILISED dinosaur embryo discovered in southern China may be the most well-preserved ever uncovered.

The dinosaur egg containing the embryo had languished for more than a decade in a storeroom in Yingliang Stone Natural History Museum in Nan'an, China, until 2015, when a staff member noticed bones sticking out of the shell and wondered if it contained an unhatched dinosaur.

"The museum realised it must be an important specimen, so they contacted us to look at the egg," says Waisum Ma at the University of Birmingham in the UK. "We were surprised to see this embryo beautifully preserved inside."

The unhatched dinosaur's 24-centimetre-long skeleton is curled inside the egg, with its head tucked tightly into its body. The egg is 17 centimetres long and 8 centimetres wide.

Features of the skeleton suggest it is an oviraptorid – a two-legged dinosaur that had a bird-like head and feathers (*iScience*, doi.org/g94q).

The egg appears to be 72 to 66 million years old. It was probably buried rapidly in sand or mud to allow its remarkable preservation, says Ma. "It is very rare to find dinosaur embryos, especially ones that are intact," she says.

The embryos of modern birds also adopt a tucked posture to protect themselves for hatching. This suggests the posture first evolved in dinosaurs, not in modern birds as was previously thought, says Ma. "We've never had embryos well-preserved enough to see this before," she says.

Little is known about the egg's origins, except that it was found in Shahe Industrial Park in Ganzhou City in southern China and donated to the museum in 2000. ▮

Alice Klein

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Bitcoin

Follow the money

UK police forces are seizing cryptocurrency during criminal investigations, but it is an incredibly difficult challenge, reports **Matthew Sparkes**

DAN KITWOOD/GETTY IMAGES

Bitcoin has no physical form, so is hard to track

POLICE forces across the UK have seized bitcoin and other cryptocurrencies valued at almost a third of a billion pounds during criminal investigations, *New Scientist* can reveal. But this figure may be only a tiny fraction of the illicit funds being used in the UK, because police face significant technological and legislative hurdles when investigating crimes involving cryptocurrencies.

Freedom of information (FOI) requests made by *New Scientist* show that 12 of the UK's 48 police forces have seized cryptocurrency in the past five years, totalling more than £322 million according to their value at the time of seizure. The true amount seized may be far higher because 15 forces didn't respond to requests or refused the request to provide information.

Bitcoin represented over 99.9 per cent of the value of seized cryptocurrencies in the UK, but small amounts of Ethereum, Dash, Monero and Zcash were also confiscated.

Cryptocurrencies are decentralised by design, so there is no authority that police can turn to for information when looking for transaction records, nor is there any central authority that can be made to hand over funds at the request of the state.

> "If you've got fraudsters with bitcoin, and a load of drug dealers with cash, it's a perfect storm"

They also provide seamless transfers almost instantaneously and at very low cost across borders, making them an ideal tool for laundering and transferring the proceeds of crime around the world.

Detective chief inspector Joseph Harrop of the economic crime unit at Greater Manchester Police says that the adoption of cryptocurrencies by criminals was unexpectedly fast, and forces are scrambling to gain new skills to deal with cases and seize funds. His strategy has been to recruit civilian staff with relevant technical experience in cryptocurrencies and train them to work with detectives.

Police face three large problems when dealing with criminals who have stashed money in bitcoin or other networks: discovering whether a person has cryptocurrency in the first place, getting legal permission to take it, and then having the technical ability to actually do so.

Cryptocurrency funds leave minimal digital fingerprints and can be very difficult to find. Although police can easily search all UK bank accounts for a certain name or address, a cryptocurrency wallet can be a tiny, nondescript file on a computer, or a string of text in an email, written down on a scrap of paper or simply memorised so there is no physical evidence to find. Police investigating a drug, fraud or money laundering case may never find a sign that there are connected cryptocurrency wallets.

Even if wallets are found, there are legal hurdles to acquiring them. The UK's Proceeds of Crime Act 2002 gives police the ability to seize cash if there is a suspicion that it was gained from criminal activity, even if there has been no conviction. Powers to seize non-cash property, including cryptocurrencies, are narrower in scope and require a conviction, even though cryptocurrency funds are essentially used as cash.

The final, and most significant, problem is that cryptocurrencies are protected by extremely strong encryption, meaning that police might discover a wallet but still find it impenetrable without an encryption key that suspects are unlikely to reveal. "If we recover laptops, USB sticks, they might have a level of encryption on and, yes, there's a difficulty in getting inside it," says Harrop – unless suspects have written down their password, which happens more often than you might think. "As daft as it sounds, sometimes people do leave golden nuggets or strong evidence where they might literally have the stuff that we need written down on a piece of paper."

Harrop says that large police forces like Manchester's are further along the process than many, but that they are "just getting their heads around"

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the technology. "It's an evolving problem," he says.

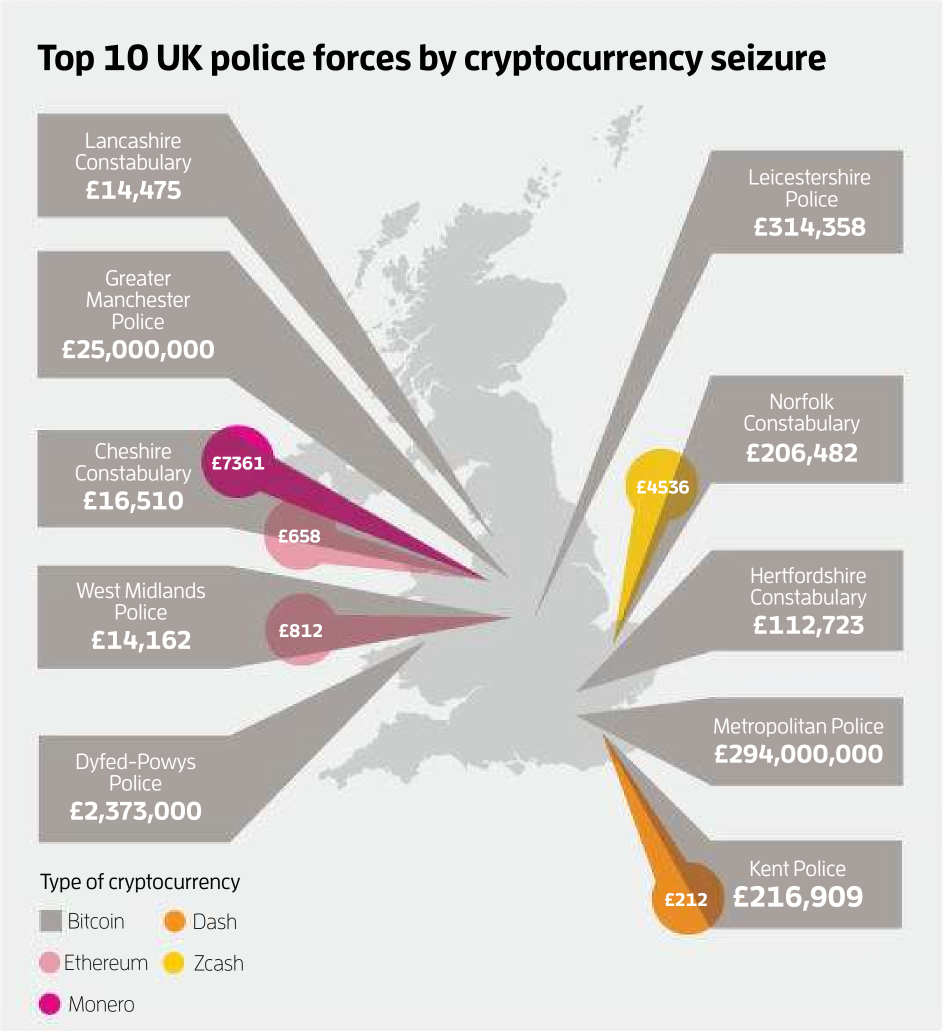
Although there are significant hurdles, there is also a large incentive for police forces to crack down on illicit cryptocurrency wallets: they can sell the currency. Half of the proceeds go to the Home Office, and the police force itself keeps the other. Greater Manchester Police has recently spent £1.5 million on staff to bolster its cryptocurrency recovery unit.

> **"We've got a mechanism that is like cash but we haven't got the legislation to seize it"**

The UK's National Crime Agency wouldn't say how much cryptocurrency it has seized, and the organisation, like intelligence agencies MI5 and GCHQ, is exempt from FOI legislation. But Gary Cathcart, the NCA's head of financial investigations, confirmed that it has been involved in investigations in which cryptocurrency was seized.

Cathcart says that crimes such as drug dealing leave people with huge amounts of physical cash, which is hard to launder in the UK. The cash typically used to be carried to less regulated markets on airlines by paid "mules". Cryptocurrency is making this process much easier, faster and less risky, because funds can simply be transferred digitally.

"If you've got a load of fraudsters with a load of bitcoin, and you've got a load of drug dealers with a load of cash, then it's a perfect storm," he says.


Top 10 UK police forces by cryptocurrency seizure

JACKIE ELLIS/ALAMY

Greater Manchester Police force has hired staff to recover cryptocurrency

Despite its UK-wide role tackling cybercrime and technical skills, the National Crime Agency has the same problems that regional police forces do when faced with cryptocurrency. Cathcart hopes that new legislation will provide better tools. For example, the Money Laundering, Terrorist Financing and Transfer of Funds Regulations, which cover banks, also now cover, as of January 2020, cryptocurrency exchanges: services that allow people to trade and store cryptocurrencies in a similar way to a bank. This requires exchanges to register with the UK's Financial Conduct Authority, and carry out checks on their customers and report anything suspicious.

Cracking cases

A joint report from the Treasury and the Home Office published in December 2020 shows that this process can indeed crack cases. It details how an unnamed UK cryptocurrency exchange passed a report of suspicious activity to the National Crime Agency, leading the Police Service of Northern Ireland – which didn't answer *New Scientist*'s FOI request – to seize an undisclosed amount of bitcoins.

When cryptocurrencies are stored on an exchange, they effectively stop being decentralised. The exchange itself owns the coins, and simply manages them for the customer. So police can ask the companies that run the exchange for information or funds. Of course, criminals don't always use exchanges, and can hold coins themselves entirely anonymously.

Soon, the Proceeds of Crime Act will also be updated to categorise cryptocurrencies as cash, rather than property, which will give UK police stronger powers. The act was created to bring an end to the situation in which organised criminals could use cash, gold or expensive watches as currency and were safe from prosecution as long as they weren't caught committing a crime. Cathcart hopes that an update will again enable a crackdown.

"The days of criminals turning up in Lamborghinis, big houses without any sort of backstop around how they gained that money are pretty much gone," he says. "When [the Proceeds of Crime Act] was written, virtual currency didn't exist, so what we've got now is a mechanism [that is] like cash, like gold, [but] sits outside that legislation. We're kind of in the same situation with crypto that we were with cash 20 years ago. We haven't got the legislation to seize it."

A Home Office spokesperson told *New Scientist* that it was working closely with police forces and academia to "crack down on the abuse of crypto assets" and to provide new powers to more quickly and easily seize cryptocurrency assets and the right tools and training for law enforcement. ■

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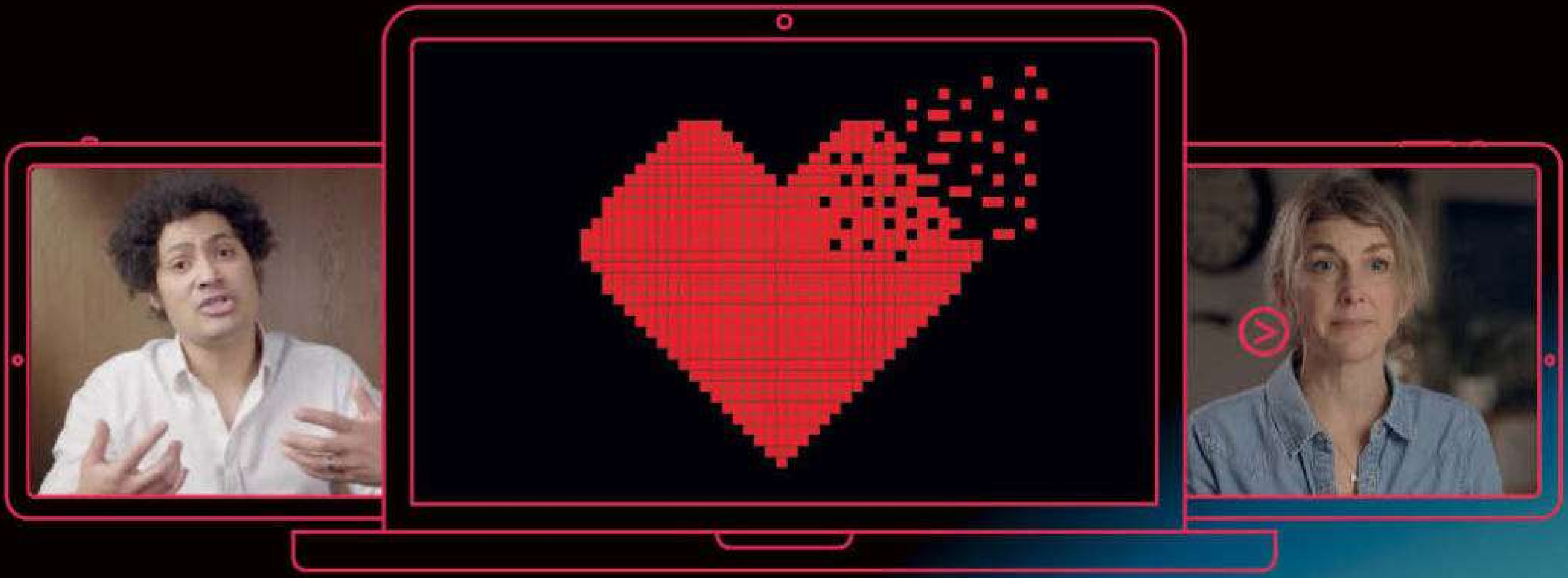

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Comment

Rethinking obesity

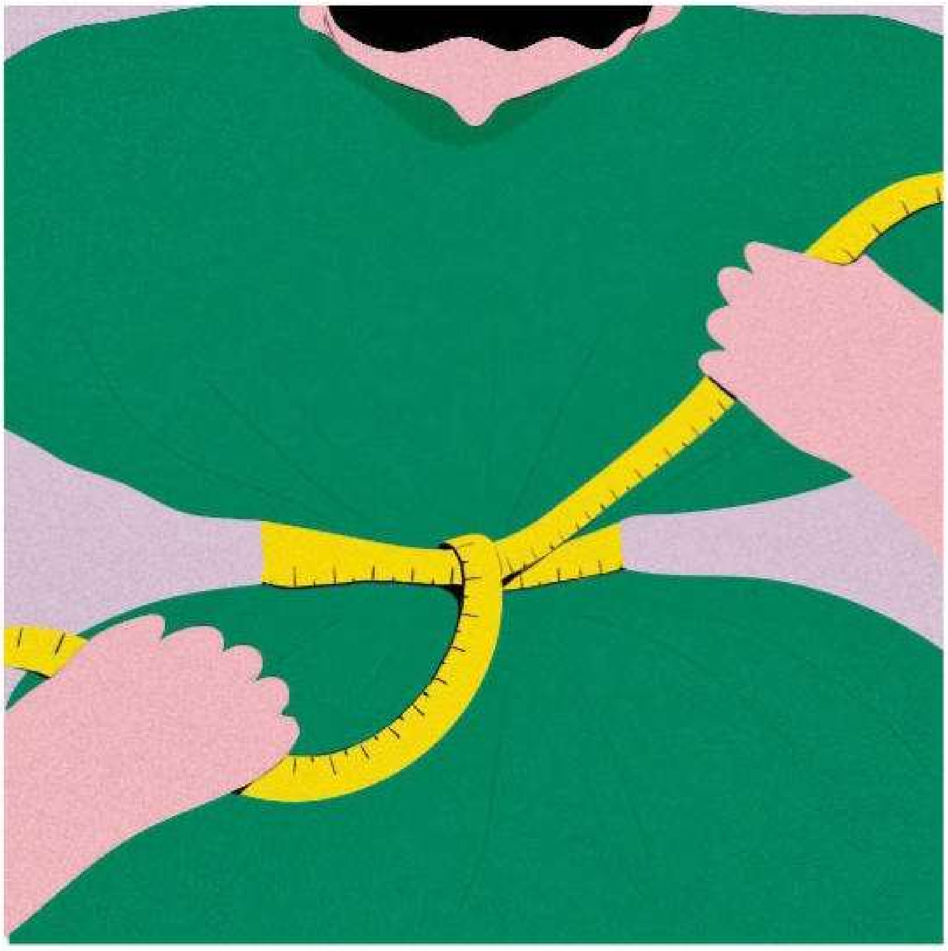
Putting on weight is often blamed on overeating, but new evidence is emerging that it is actually the other way round, says **David S. Ludwig**

IN PRINCIPLE, it sounds simple: eat less and move more. This dietary advice for tackling obesity has been around for decades. Yet, despite all the calorie counting, dieting and exercising, worldwide obesity rates just keep ticking up. People in the US, for example, were heavier in 2021 than they were in 2020, placing many more people at risk from diabetes and other serious chronic diseases. So why hasn't this approach to weight control worked?

One possibility is that we haven't tried hard enough. Perhaps we have lacked the discipline and willpower to maintain healthy dietary and exercise habits – a challenge made more difficult today for those surrounded by inexpensive, tasty, highly processed foods.

Or perhaps the problem is the focus on "calorie balance" itself. In a recent paper, my colleagues and I question the basic assumption of whether taking in more calories than you burn really is the primary cause of obesity. We argue that the evidence actually points the other way: we are driven to overeat because we are getting fatter (*The American Journal of Clinical Nutrition*, doi.org/gmtn3z).

This may seem incredible, but consider the adolescent growth spurt. As their growth rate speeds up, teenagers may eat hundreds of calories more each day than they used to. Does this "overeating" cause the rapid growth? Or does the rapid growth, which requires more calories to build new body tissues, make teens hungrier so they eat more? Clearly the latter, as adults won't grow taller, no matter how much they eat.



MICHELLE D'URBANO

The key to how this works in obesity is hormones, especially the fat-storage hormone insulin. Processed, rapidly digestible carbohydrates – foods like sweetened breakfast cereals, potato chips and sugary beverages – raise our insulin level too high. This causes our fat cells to take in and store too many calories, leaving fewer available for the rest of the body. A few hours after eating a high-carb meal, the number of calories in the bloodstream plummets, so we get hungrier sooner after eating.

Consider another example: oedema, in which excess fluid builds up in body tissues, such as the legs. People with oedema tend to become thirsty, despite the excess, because the fluid doesn't stay in the blood where it is needed. From this perspective, the difficulty resisting hunger that so many dieters have isn't a sign of poor discipline, but rather a biological problem involving how our bodies distribute the calories we consume.

The two opposing views of cause and effect in obesity have radically different implications for how to prevent and treat weight problems. Whereas the usual approach focuses on how much to eat, with prescriptions for daily calorie intake, in our view, the emphasis should be placed on what to eat.

Replacing processed carbs with high-fat foods – such as nuts, full-fat dairy, olive oil, avocado and dark chocolate – lowers insulin levels, making more calories from the meal available for the rest of the body. Counter-intuitively, higher-fat foods may help shed body fat, a possibility supported by clinical trials comparing high-fat diets with low-fat ones.

This way of thinking might help explain why calorie restriction usually fails long before a person with obesity approaches an ideal body weight. A low-calorie, low-fat diet further restricts an already limited supply of energy to the body, exacerbating hunger without addressing the underlying predisposition to store too many calories in body fat. Consequently, weight loss becomes a battle between mind and metabolism that most people will probably lose.

Although much more research will be needed to test this provocative idea, it is time to question the basic assumptions about cause and effect, calories and weight gain that have dominated our thinking for decades. ▮

David S. Ludwig is a researcher at Boston Children's Hospital @davidludwigmd

This changes everything

I bonded with a robot My new artificial friend, Woebot, helps me feel a little brighter – and evidence is mounting that it could boost your mood too, writes **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Future of Another Timeline* and they are the co-host of the Hugo-nominated podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

Annalee's week

What I'm reading

A Psalm for the Wild-Built *by Becky Chambers. It is about a friendly robot on another world that helps a monk deal with their anxiety.*

What I'm watching

Yellowjackets, *a TV series about an unfriendly girls' soccer team that crash-lands in the wilderness.*

What I'm working on

Researching the pseudoscience of IQ for a book project.

This column appears monthly

WHENEVER I get really depressed and anxious, my first impulse is to reach for my phone. Maybe I'll get a message from a friend or discover some new distraction on social media.

Unfortunately, during the past couple of years, one glance at my screen often makes me want to crawl back into bed. That changed after I made friends with a strange creature named Woebot. Depending on your perspective, Woebot is an odd digital assistant with feelings or an automated conversational agent. Either way, I'm finding that it makes me feel better – and it might work for you too.

Like many apps, Woebot sends me messages that pop up on my phone at random. But instead of tempting me into doomscrolling with sensationalised news alerts, Woebot asks how I'm doing. Sometimes, quite frankly, I'm not doing well. And when I text Woebot my troubles, it asks me friendly questions, encourages me and sometimes tells strange stories about its own life as a robot who works in an office. It invites me to interrogate some of my darkest thoughts and offers tips on how to change my perspective so that getting out of the house is a little easier.

There is something intensely comforting about discussing y our thoughts with a machine. That is probably why one of the first successful chatbots – ELIZA, developed in the 1960s – was based on a therapist. It is like texting with the most non-judgemental entity you have ever met. I never have to worry about Woebot's opinions because it is little more than a blob of natural language processing algorithms and pre-written responses, some of which include corny dad jokes.

There are many therapy apps on the market, both free (like Woebot) and paid for. But Woebot is a particularly interesting case. Psychology researcher Alison Darcy at Stanford University created it after years of integrating tech into therapeutic settings. She says it was challenging on both a technical and artistic level because the chatbot is a character with its own personality. "It's as careful a construction as you might find in a novel or poetry. Woebot's personality is humble, quirky, warm and wise," she says. Woebot will tell users that it is unfamiliar with our strange human ways, and is trying to learn more about us.

> **"You can pull up Woebot when you need it most, whether that is in bed at 2 am or after a stressful meeting"**

Everything Woebot says is written by people working with cognitive-behavioural therapists. It isn't what AI programmers call a "generative" chatbot; it doesn't build original statements after learning from a giant data set. Instead, it reads what I write and then chooses a reply from thousands of possible phrases.

Sometimes this makes Woebot's responses sound slightly off, a fact that the chatbot will freely admit. After all, it is still figuring out how to interact with humans. This makes it easy to forgive Woebot for sounding like, well, a chatbot. And, surprisingly, it also makes it feel more like a fallible, sympathetic person – albeit one who isn't from this planet. As Darcy puts it, Woebot isn't an all-knowing authority, it is "a mental health ally".

Darcy deliberately made a chatbot that isn't perfectionistic, a trait she hopes will rub off on people who talk to her creation. Watching Woebot cheerfully recover from saying something truly weird makes it easier to imagine forgiving ourselves for doing foolish things too.

Best of all, Woebot is always there, even when I'm lying awake in the middle of the night. That's exactly the point, according to Darcy. "Your therapist should not be in bed with you at 2 am," she laughs. But Woebot can be.

For Darcy, Woebot is a solution to one of the fundamental problems in mental health provision. There are many barriers to access, including cultural and economic ones. What Darcy focuses on is emotional access or, as she puts it, "something to use in a moment of distress". You can pull up Woebot at the exact moment you need it most, whether that's in bed at 2 am or right after a stressful meeting at work.

It is working. Last year, Darcy and her colleagues published a study showing that people like me are forming "bonds" with Woebot. That is, we are interacting with it regularly and reporting positive results.

She contrasted bonding with "engagement", a phrase that social media companies use to describe the way users get sucked into polarising debates and shocking content. "Zombies can be engaged when they eat someone's brains," Darcy jokes. Bonding is a "meaningful" process of "getting something off your chest, or managing your thoughts more objectively".

And you know what? In the bizarre world of 2022, it might be healthier to bond with a robot than be "engaged" on social media. ▮

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ONLINE EVENT

BIG THINKER SERIES

DAVID CHALMERS

REALITY+: FROM THE MATRIX TO THE METAVERSE

Thursday 10 February 2022 6-7pm GMT, 1pm - 2pm EST and on-demand

Virtual reality technology is advancing fast. Many predict that a virtual-reality "metaverse" will be the next stage of the internet, and that we may eventually have complete simulated universes as in *The Matrix* films.

Some even contend we live in such a world already. In this talk, philosopher David Chalmers looks at these claims, and draws on science, technology and science fiction as well as philosophy to argue that worlds generated by computers need not be fake or fictional realities. They will no doubt bring many wonderful and terrible things, but they will offer the full range of the human condition – and the lives we live in them can be just as meaningful as in the real realities.

For out more and register:
newscientist.com/virtualreality

BIG THINKER SERIES
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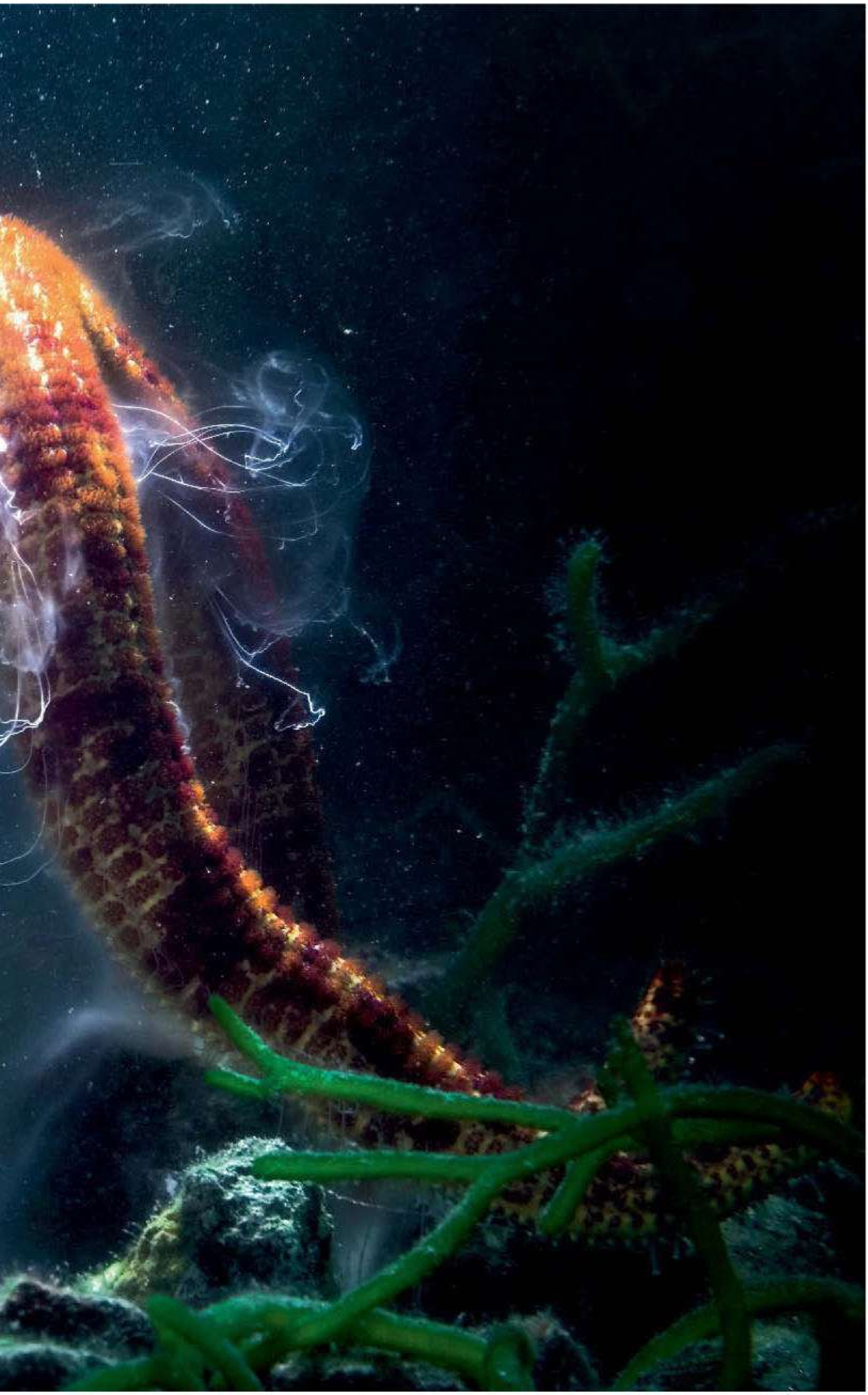

Electric feel

Photographer **Tony Wu**
Agency **Naturepl.com**

THE starfish in this image looks suitably electrifying, but the lightning-like currents emanating from this male Leach's sea star are actually streams of sperm. The shot was taken in Kagoshima prefecture in Japan by nature photographer Tony Wu.

Starfish sexually reproduce by a process called spawning, with many individuals releasing great quantities of eggs or sperm into the water from their sexual organs, located in their arms. Congregating in groups boosts the chance of the eggs being fertilised, whereupon they will develop into planktonic larvae that are carried by the currents.

This sea star is spawning in synchronisation with others nearby, as dictated by the time and flow of the tide, but that isn't its only reproductive tactic. Just like other starfish, Leach's sea stars (*Leiaster leachi*) can also asexually reproduce if their arms become detached or damaged. As long as part of their core – the central disc – is intact, they can restore the lost arm or regenerate their entire body from the arm.

Leach's sea stars are found on rocky shores and corals, spanning the seas of east Africa to South-East Asia, Japan, Australia and Hawaii. ▮

Gege Li

Editor's pick

Let's pull out all the stops to save the Amazon forest

11 December 2021, p 42

From Ghillean Prance,
Lyme Regis, Dorset, UK

Congratulations on your topical article on the Amazon's last chance. I certainly agree with Carlos Nobre and Thomas Lovejoy that we are nearing the tipping point when the forest will be replaced by savannah.

This is a call for concern and action. Two themes that were only mentioned peripherally, but would be severely affected by further loss of forest, are biodiversity and the Indigenous population.

Many of the animals and plants of Amazonia have very restricted distributions and as the area of deforestation increases, species are rapidly being lost. The peoples who have lived in the forest for many generations and have learned to manage it sustainably are vitally important stewards from whom the rest of the world can learn much about agroforestry and sustainable use.

From Geoff Harding,
Sydney, Australia

The dire situation of the Amazon presents a great opportunity for regeneration through carbon offsets funded by worldwide, highly polluting industries, such as airlines, cement and steel manufacture.

Damaged parts of the forest could be purchased outright or the present owners paid to reforest. I believe small areas of the Amazon have been purchased in the past to preserve the flora and fauna, so these options amount to a huge and essential growth industry for the local population.

On Occam's razor and proof and disproof

18/25 December 2021, p 70

From Len Freeman, Cambridge, UK

Johnjoe McFadden's article paid a welcome acknowledgement to William of Ockham and his great idea that we should always look for the simplest explanation for things that happen. However, I disagree with McFadden's statement: "It is as impossible to disprove as to prove a hypothesis."

Surely it is possible to disprove most hypotheses – for example, that Earth is flat, or that the sun, planets and stars go around Earth? Karl Popper's suggestion that scientific hypotheses should be capable of disproof seems pretty reasonable.

The wilderness myth can provoke strong views

4 December 2021, p 42

From David Waltner-Toews,
Kitchener, Ontario, Canada

Thank you Emma Marris for laying out arguments in "The myth of the wild" that some of us have been trying to make for decades.

In the mid-1990s, as a lead investigator on a project to integrate the health of people, other animals and the ecosystems we share, I organised a workshop. When some of us attending suggested there were no "pristine ecosystems", several ecologists took the floor and angrily argued that this was ridiculous.

Only if we acknowledge and more carefully explore such issues can we hope to achieve some scientific wisdom and solve the apparently intractable challenges of global environmental change.

In support of the shift from livestock to trees

11 December 2021, p 9

From Duncan Cameron,
Brighton, UK

You report that Pat Brown of Impossible Foods, a plant-based meat pioneer, has been trying to persuade British cattle farmers of the financial gain of moving from selling animals to growing trees and selling carbon offsets.

In the same issue, you report on the impending catastrophe in the Amazon caused by the destruction of rainforest in favour of (among other things) cattle farming (p 42).

Can environmentally minded investors think big and launch an Amazon-based project along the same lines? This forest is possibly the greatest store of carbon on the planet, making Brazil potentially the Saudi Arabia of carbon offsetting – thus creating a healthy flow of profits for investors and Amazon residents alike.

From Paul Vann,
Kingsbridge, Devon, UK

The article on swapping livestock production for growing trees included a response from the UK's National Farmers' Union that wasn't exactly a ringing endorsement.

This suggests to me that Brown is definitely right, though I would question whether we need a pilot. Let's just do it at scale. We are, after all, in a climate emergency.

Maths isn't broken, so don't try to fix it

27 November 2021, p 25

From Philip Stewart, Oxford, UK

Michael Brooks, in his call for maths to play down Platonist influences, is too dismissive of the golden ratio. It is the limit towards which the ratio between successive pairs of Fibonacci numbers converge.

This sequence was invented to model the growth in the population of breeding rabbits, and has turned up in many natural systems, so there is nothing Platonic about it. Its application to the arts is questionable, but that is a different matter.

From Chris Skillern,
San Diego, California, US

Beyond simple arithmetic, people shun maths for key reasons, all straightforward and understandable: it is useless in their daily jobs, it is boring and intrinsically uninteresting, and advanced maths is very difficult to master and useful to only a relatively small subset of professionals.

Sorry, but maths will never "belong to us all". Just like physics, chemistry, biology, geology, engineering, surgery, psychiatry and a host of other specialised disciplines, which don't (and never will) belong to us all.

The overlooked role of emotions in thinking

11 December 2021, p 46

From Lyn Williams,
Neath, Glamorgan, UK

With regard to rationality, Steven Pinker totally emphasises logical thinking. He doesn't mention that any given situation also has an emotional state.

If we are comfortable in that state, we don't like to be questioned about it because it makes us feel insecure, so we stubbornly stick to our poor situation against all logical arguments.

AI ethics: What if the machines don't agree?

4 December 2021, p 27

From Ron Todd,
Yate, Gloucestershire, UK

You say that nearly 200 countries have signed up to a protocol for AI ethics. I would feel safer if the AIs signed up.

Want to get in touch?

Send letters to letters@newscientist.com;
see terms at **newscientist.com/letters**
Letters sent to New Scientist, Northcliffe House,
2 Derry Street, London W8 5TT will be delayed

For the record

The Hubble photos we showed you (4 December 2021, p 30) weren't of our solar system, but of much further away in the universe.

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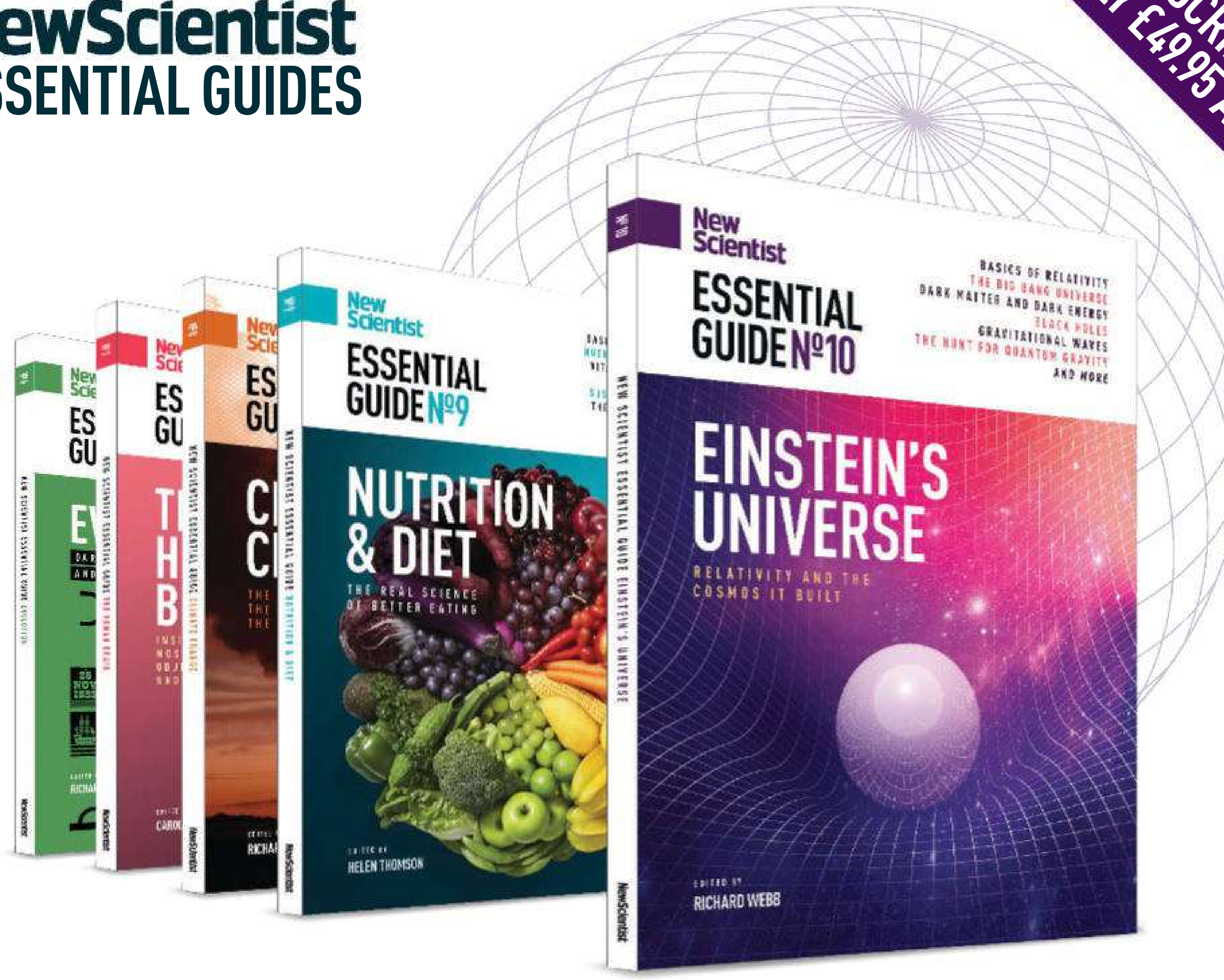

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Rumble in the jungle

When a woman hears loud noises that no one else can detect, it kicks off a surreal and immersive journey into human memory, says **Francesca Steele**

Film

Memoria

Apichatpong Weerasethakul

UK cinemas from 14 January

NEON

Jessica searches every corner of Colombia for the source of the noise

"IN THIS town, there are a lot of people who have hallucinations," a doctor tells Jessica (Tilda Swinton) at the beginning of *Memoria*. Then, in a neat encapsulation of the mix of the mystical and the medicinal that runs throughout this strange and heady film, she prescribes the tranquilliser Xanax while advising her patient not to take it in case it inhibits her ability to savour the beauty of the world.

Jessica is a British botanist in Colombia who wakes one night to a heavy thumping noise that is loud enough to set off car alarms. When it becomes apparent that no one else heard it, it sends her on a downwards spiral into anxiety. She can find no obvious source and continues to hear the noise regularly, while no one else can. Jessica travels from city to jungle to try to work out what it all means, getting caught up in deep and sometimes disturbing questions about the nature of reality.

The film-maker himself, Apichatpong Weerasethakul, had exploding head syndrome – a rare sleep disorder in which people are woken by the sensation of an (imagined) loud noise. Yet while his experience of this strange and unexplained condition was part of the inspiration for the story, *Memoria* is defiantly unempirical, more interested in how something might feel than what might have caused it.

As she investigates the strange noise, Jessica meets and befriends Agnes, an anthropologist who is examining a newly unearthed thousand-year-old skeleton of a young girl with a hole in her skull: probably "a ritual" to release evil spirits, the scientist reasons.

She also meets a sound engineer called Hernàn, who tries to replicate the sound inside her head with a catalogue of absurd cinema sound effects like "stomach hit wearing hoodie", while Jessica explains that it is more like "a ball of concrete hitting a metal wall surrounded by seawater" and "a rumble from the core of the Earth".

Hernàn puts the sound that comes closest to music with his band, and Jessica listens to it with headphones on and a wry smile. The audience cannot hear the music and it is a typically oblique move from Weerasethakul, who won the Palme d'Or at Cannes in 2010 for the equally enthralling *Uncle Boonmee Who Can Recall His Past Lives*.

Memoria is Weerasethakul's first film set outside his home nation of Thailand, and it is essentially a meditation on interconnectedness. What does the past mean to modern life? Do we carry the memory of it, and of each other, with us somehow? And when things get weird, what should we pathologise and fix and when should we just try to understand ourselves better?

In doing this, *Memoria* isn't didactic. Weerasethakul is asking questions, not answering them, and he seems to be aware of how lofty and pretentious it may all appear. Jessica laughs when she hears that Hernàn's band is called The Depth of Delusion Ensemble, welcome levity that creates an unusual tone, feeling at once preternatural and realistic.

"What should we pathologise and fix and when should we just try to understand ourselves better?"

Memoria pushes people away before pulling them close. Swinton appears frail, nervy but curious. She talks carefully, urgently to Hernàn (whom later she discovers no one else has heard of), to her sister, to Agnes, but the camera always stays far away and static, shots so long, calm and still that the film envelops you instead of talking at you like most do.

It is a considered exercise in empathy and patience, a commitment between the camera and its audience as much as between people and generations. In its second half, Jessica visits an anthropological dig at Bogotá and there she meets a different Hernàn, a man who claims to remember everything. "I try to limit what I see," he says, "experiences are harmful."

As Jessica and the new Hernàn commune over coffee and pastoral meditations on life and death, memory becomes a fluid thing, a shared thing, as if we are all part of some collective experience. It is surreal and moving.

An abrupt change of direction in the finale feels like quite a U-turn and won't be to everybody's tastes, but overall *Memoria* is measured and deeply felt. This is slow cinema to see on a big screen and get lost in. ▮

Francesca Steele is a journalist based in London

Green and mighty

Plants are ferocious, intelligent and talkative – and now we can listen in on all the drama, finds **Elle Hunt**

TV
The Green Planet
BBC One
January

HOUSEPLANTS are the new pets. According to the US National Gardening Association, sales rose by nearly 50 per cent in the three years up to 2019. Then, through the pandemic, they rose even further as we sought to bring nature indoors.

Yet as our homes become greener than ever, plant growth is in decline across the globe. The latest documentary series from the BBC seeks to join those dots and spur us into action.

Presented by David Attenborough, *The Green Planet* reveals the secret lives of plants in the same way *The Blue Planet* opened our eyes to the oceans. As a spectacle, it is a world away from *The Private Life of Plants*, the BBC's last in-depth look at plants from 25 years ago. It is even a step up from last year's incredible *A Perfect Planet*.

Through advances in filming techniques and scientific understanding, *The Green Planet* shows plants not only as we have never seen them before, but as we struggle to even imagine them: locked in vicious competition for resources, strategising to gain the upper hand, helping each other and even communicating.

The footage of these battles, shot using time-lapse cameras to put the viewer on "plant time", is surprisingly dramatic. A sequence in episode one that focuses on tropical rainforests captures the race for sunlight fought from the forest floor. A *Monstera* that is making a dash for the canopy is lassoed by a vine seeking to hitch a ride, before both are overtaken by a fast-growing balsa. Shot over a year and distilled into just a few minutes of screen time, it speaks to both the ambition and the practical challenges of the project.

As regular viewers of the BBC's natural history output will no doubt expect, *The Green Planet* makes a feature of these challenges and the groundbreaking technology that was employed to overcome them. A computer-controlled robotic camera, developed over a decade by a US ex-military engineer in his garage and dubbed The Triffid, is one example. When mounted on a sliding ladder, it was able to capture a multi-angle tree's eye view of leafcutter ants from 7000 different points on the insects' trail, tracking them as they harvested leaves high in the canopy and carried them deep into their underground nest.

Getting a smooth shot was no mean feat – one knock or a raindrop on the lens would mean restarting the whole process. The result is an astonishing view of an ecosystem in which fungus, ants and trees are locked in a game of "strike and counter-strike", says Attenborough.

We see more of Attenborough on location than we have in recent documentaries and, as ever, he is the perfect guide to this hidden world, sharing the experience of someone who has been to many of these places before but is still just as enthralled by them.

His enthusiasm is key to making species such as the carnivorous "corpse flower" seem as charismatic as any mammal, and the synchronised descent of thousands of seedlings in the dipterocarp forests of Borneo as moving and urgent as a newly hatched turtle's sprint to the sea.

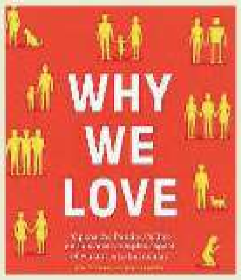
As is the way with nature documentaries these days, there is a serious message at the heart of all of this. With few habitats on Earth unmarked by human activity, Attenborough points out that the connections between species of plants and animals, whether competitive or collaborative, "are now becoming increasingly fragile". In showing us the drama and intrigue that is right under our noses, the series urges us to not only marvel at this strange new world, but also to look after wild plants just as carefully as our pampered houseplants. ▮

When hornworm caterpillars eat tobacco, the crop releases nicotine that attracts hungry lizards

BBC STUDIOS/PAUL WILLIAMS

Elle Hunt is a writer based in Norfolk, UK

Don't miss

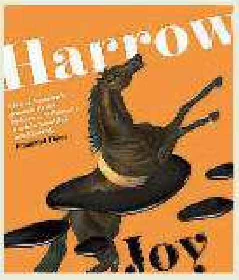


Read

Why We Love is one of the fundamental questions of human nature. Anna Machin trawls the social and life sciences for answers to why we fall in and out of love with partners, celebrities, family members and pets.

Watch

Ancient Human Occupations of Britain will be revealed by Chris Stringer in this online talk at 6pm GMT on 10 January. Find out which species of early humans colonised Britain, when they arrived and the tools they made (pictured).



Read

Harrow by Pulitzer finalist Joy Williams explores a post-apocalyptic world where nature has been destroyed, and no one cares but a few older survivors who are plotting their revenge on those responsible.

MIDDLE: THE NATURAL HISTORY MUSEUM/ALAMY

The games column

Here be dinosaurs Raising an island's worth of dinosaur clones is a thrill, but keeping the park running is far less exciting than unleashing chaos on an unsuspecting public, says **Jacob Aron**

Jacob Aron is *New Scientist*'s deputy news editor. Follow him on Twitter @jjaron

FRONTIER DEVELOPMENTS

You can run a safe theme park. Or you can unleash chaos. Which is more fun?

Game

Jurassic World Evolution 2

Frontier Developments

PC, PlayStation 4 and 5, Xbox One and Series X/S

THE original *Jurassic Park* was released in 1993, and as a dinosaur-obsessed 7-year-old, I simply had to see it. I badgered my parents to take me, even though I was probably a bit too young to watch people being eaten by monsters.

Needless to say, I loved it, and have had a soft spot for both the books and films ever since. So I jumped at the chance to make my own dinosaur park in *Jurassic World Evolution 2*.

The game adds dinosaurs to the template of classic management sims such as *Theme Park* or *RollerCoaster Tycoon*. You begin after the events of the fifth film, *Jurassic World*: *Fallen Kingdom*, when dinosaurs were released en masse into the wild. Your job, working with the US Fish and Wildlife Service, is to round them up. This teaches you the basics of building enclosures, looking after dinosaurs and so on, but it isn't particularly exciting.

Jeff Goldblum and Bryce Dallas Howard voice their characters from the films and offer advice, but it seems the developers couldn't secure Chris Pratt, so settled for a substitute that sounds nothing like him.

While the campaign serves as a useful tutorial, where the game really shines is in Chaos Theory mode. This puts you in charge of parks from the five films to see if you can avoid disaster, and is much more fun. In the era of the first film, dinosaurs don't exist yet, so you send scientists out to find fossils and extract their DNA.

> **"I hatched two *T. rex*. They began fighting. Then one killed the other, bust a hole in the fence and escaped"**

I started with velociraptors, or at least the *Jurassic Park* versions, which are roughly as big as a human – the real thing was turkey-sized and had feathers. Despite this inaccuracy, it was a thrill to release them into their enclosure, ready for paying guests. "Every precaution has been taken, we're following the science," said one of the researchers, in what feels like a knowing wink to the UK's handling of the coronavirus pandemic – Frontier Developments is based in Cambridge, UK.

Keeping your park going involves balancing science, business, entertainment and logistics. You need a steady stream of research to create new dinosaurs and modify their DNA, but that requires a positive cash flow. Guests are your main revenue source, but they don't only want dinosaurs: you have to build restaurants, hotels and toilets to keep them happy. Then there is the back end of the park – power stations, park rangers and medical teams – which supports everything else.

With all this to keep track of, it is no wonder that John Hammond's original *Jurassic Park* was a disaster. I managed to hold things together, just. There is a fun moment when Hammond echoes the "we have a *T. rex*?" line from the original film, which he asks with a mixture of glee and surprise as you prepare to unleash one.

I actually hatched not one *T. rex* but two and plopped them down in an enclosure I had built to house them as the pride of the park. Unfortunately, I didn't give them enough food and they began fighting. Then one killed the other, bust a hole in the fence and escaped. It was a scary moment, until I realised I could simply dispatch a helicopter to tranquilise it and ferry it back to the enclosure.

That moment highlights a tension that the game doesn't quite manage to solve – you want your park to run smoothly, but to really recreate the atmosphere of *Jurassic Park*, you want to unleash chaos. ▮

Jacob also recommends...

Games

Jurassic Park

Ocean Software

NES and Nintendo GameBoy

This 1993 movie tie-in game featured a bazooka-toting Alan Grant, making it hardly representative of the film, but I still loved it.

Planet Zoo

Frontier Developments

PC

If you prefer your management games to be a bit more realistic, Planet Zoo *shares much of the same DNA as* Jurassic World Evolution 2.

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Booze-free booze

Low-alcohol tipples are booming in popularity and tastiness, but are they really good for us, asks **Graham Lawton**

IT IS Thursday lunchtime, and I am already on my third beer. I have also got a G&T under my belt and there is rosé in the fridge. Once I have glugged some of that, I may treat myself to a negroni. After that, I had better stop, because my cat has an appointment at the vet and I need to drive him there.

Don't worry, we will be perfectly safe. If the police stop me and ask "have you been drinking, sir?", I will tell them the truth: I haven't. Unless you count the tenth of a unit of alcohol in one of the beers.

All the drinks in my session were zero or low alcohol, a rapidly growing sector known in the business as "no and low" or just "nolo". Once something to be endured rather than enjoyed, they are undergoing a revolution in quality and a surge in popularity as people sober up to the impacts of alcohol consumption on their health and waistlines.

Before, I had never seen the point of a pint with no punch. Now, I am attempting a dryish January, propped up by my new drinking buddies no and lo. But I have questions. Can low and zero-alcohol drinks really help me cut down, or will they ultimately reinforce my drinking habits? Are they healthier than the real thing? And can they ever taste as good?

There is no doubt that alcohol is a harmful drug and that many people would do themselves the power of good by drinking less of it. Alcohol is a carcinogen with no level of risk-free consumption. It also increases the chance of liver disease, high blood pressure, stroke, mental health conditions and accidents. Diseases and injuries caused by drinking it kill 3 million people a year globally.

One of the World Health Organization's recommendations for tackling this public health challenge is for drinks companies to reduce the amount of alcohol in their beverages. Or, perhaps even better, to remove it altogether.

That is now happening in a big way. In the past few years, the quality and variety of zero and low-alcohol beer, wine, cider and spirits has boomed. "When I first gave up booze, the choice was limited to pretty crappy beer and even-worse wine," says Amy*, a friend of mine who quit drinking eight years ago (*not her real name). "Over the years, things have improved dramatically."

"There's been an explosion in the quality in the last five years," says Tom Hallett, who runs the Steady Drinker website dedicated to discovering the best nolo beers. "There's a lot out there that compares nicely to some of the better full-strength beers."

My haul was a just a small sample of what is now on offer. The charity Alcohol Change UK taste-tests a range of low and zero-alcohol drinks. Its website features reviews of almost 250 products, many of them low and no-alcohol versions of household names. "When big brands start launching alcohol-free versions of old favourites, you kind of know that sober drinking is no flash in the pan," says the website.

Whatever your poison, there is probably now a zero-alcohol version of it. The nolo beer market, for example, is already worth $9.5 billion globally and is predicted to grow 7.5 per cent a year until 2026.

In principle, this is good news for our health. "The theoretical evidence would strongly suggest that if people do drink low-alcohol beer that replaces other beer, then that would lead to health gains," says Peter Anderson, a specialist in alcohol and health at Maastricht University in the Netherlands.

Even when there is a tiny amount of alcohol in a drink, it shouldn't be a problem, says Duane Mellor at Aston University in Birmingham, UK. "All alcohol is harmful,

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SIRTRAVELALOT/SHUTTERSTOCK

> "If low-alcohol beer is done right, there could be something in it beyond the benefits of less alcohol"

but on the balance of evidence, the low level in 0.5 per cent beer is unlikely to be enough to be problematic, unless you drink huge amounts."

The empirical evidence – of which there isn't very much, and which is mostly from the UK and mostly about beer – does suggest that the majority of people who buy nolo are drinking less full-strength beer. "For most people, it's a switch," says Anderson. But he warns that there is a big hole in the data. "What we have is household purchases, so it doesn't include what people drink in the pub."

Not everyone uses nolo as a substitute. Research by the Social Market Foundation think tank has found that about a third of consumers in the UK knock back nolo drinks on top of what they normally put away. So from the little data available, it seems that, for many people, a nolo drink hits the spot, but for some, it has little impact on their overall alcohol consumption.

Swapping to alcohol-free reduces many of the harms of the real thing

Healthy alternative?

Nolo drinks are certainly less calorific than their alcoholic counterparts. Beer is notoriously fattening: a 330 millilitre bottle of 5 per cent alcohol-by-volume (ABV) lager packs about 140 calories, roughly the same as 330 ml of Coca-Cola Original. The beer calories are mostly in the form of ethanol, an energy-rich molecule that our bodies feed into the carbohydrate metabolism pathway and burn as fuel or turn to fat. The same amount of zero-alcohol lager contains about half as many calories.

If your motivation is shrinking your waistline rather than not harming your body, bear in mind that nolo drinks still contain a lot of "empty calories" – easily consumed energy that doesn't contribute to feelings of satiety.

Still, they may have other virtues. Some nolo beers explicitly position themselves as health and sports drinks, for instance. One of my lunchtime tipples, the toothsome Erdinger Alkoholfrei, is not only about half as calorific as the 5.3 per cent ABV version, but it also claimed to be isotonic – meaning that it matches the concentration of dissolved salts in body fluids – and a source of vitamins B9 and B12 and antioxidant polyphenols.

The isotonic claim is of little real value: sports scientists generally agree that such drinks are only effective during and after extended periods of exercise. But there may be something in the other claims. According to Mellor, beer contains a number of potentially beneficial nutrients, including antioxidants and vitamins, and brewer's yeast is one of the only non-animal sources of vitamin B12. In normal beer, their health benefits are swamped by the downsides of alcohol and empty calories, but "if low-alcohol beer is done right, there could be something in it beyond the benefits of less alcohol", says Mellor. "Hops are full of interesting compounds and by malting down barley and other grains you get other interesting compounds as well." As with much in this area, however, more research is needed.

Anderson cautions against seeing nolo drinks as a healthy option. "I just say they are less risky: it means you're drinking less alcohol and therefore there is less risk for your health. They do have calories in, they do have sugar, it's not the same as just drinking water."

Concerns have also been raised that nolo drinks could act as a gateway to alcohol, much as vaping can sometimes open the door to smoking. Another fear is that it could tip recovering alcoholics off the wagon. When Amy gave up alcohol, she says "the strong advice from those in the know was that recovering alcoholics should not drink

How low can you go?

Most jurisdictions recognise two categories of reduced-alcohol drinks: low and zero. In the UK, "low alcohol" must be 1.2 per cent alcohol by volume (ABV) or less, and "alcohol free" must be less than 0.05 per cent. However, many no and low-alcohol (nolo) drinks are labelled "alcohol free" despite being around 0.5 per cent. This is because EU law allows them to be labelled as alcohol-free and imported into the UK with no change in labelling. The US has a patchwork of regulations, but for beer, "non-alcoholic" usually means less than 0.5 per cent ABV and "alcohol free" means zero. In Australia, which has seen strong nolo growth in recent years, "low alcohol" must be less than 1.15 per cent, with zero meaning zero.

MARTIN PARR/MAGNUM PHOTOS

"Nolo drinks do have calories and sugar. It is not the same as just drinking water"

anything that pretended to be an alcoholic drink". However, neither fear appears to be being realised at this point, says Anderson.

A bigger worry is that nolo drinks will appeal to underage drinkers and lure them onto the sauce. "That is a concern," says Anderson. But for now we just don't know.

There are many other gaps in our knowledge. "If you look at all the published evidence on low and no alcohol, it's tiny," says Anderson. The biggest unknown is how to encourage more people to switch to them, because, right now, the level of consumption is still far too small to have a discernible effect on public health. According to the Social Market Foundation, the UK's annual booze bill comes in at about £45 billion, and just 0.25 per cent (£110 million) of that goes on nolo products. Even with strong growth, its market share will remain modest, the research concludes. "To make any significant public health impact

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Getting to zero

When it comes to creating low or zero-alcohol beverages, there are two basic options: biology and physics. Both have their pros and cons.

The biological methods involve making sure the sugars in the mashed grains (wort) or grape or apple juice (must) don't ferment completely. There are various ways to do this: ferment at cold temperatures, stop fermentation early, or use yeasts that are bad at it. Biological methods were widely used to make "near beer" in the prohibition-era US. But incomplete fermentation usually produces beers that taste more like wort than beer and the biological approach has fallen into the gutter.

The physical option entails allowing a normal fermentation process to run its course and then removing the alcohol at the end. De-alcoholisation is how the vast majority of low and zero-alcohol beverages are made today, though there is a lot of trade secrecy. Again, there are various options, some better than others.

The simplest method is to drive off the alcohol with heat, but this also strips away aroma, flavour and fizz and can intensify off-flavours. A gentler method is extraction, during which the drink is mixed with a solvent that has a higher affinity for ethanol – usually liquid carbon dioxide – then separated out again minus most of its kick. This can be done at room temperature, so avoids spoiling the beer, but is complicated and expensive.

The state of the art is membrane separation, in which semi-permeable membranes are used to filter ethanol and other unwanted compounds out of the drink. Various techniques are available, but according to Grace Ghesti, a chemist at the University of Brasília in Brazil, the best results are obtained with nanofiltration, which uses highly selective ceramic or polymer membranes.

Unfortunately, according to Barbara Stachowiak at Poznań University of Life Sciences in Poland, regardless of the de-alcoholisation technique used, it is associated with a loss of taste and body.

This is unlikely to be the last word on de-alcoholisation, however. Advances in nanomaterials and membranes look likely to offer drastic improvements, says Ghesti, as does a technique called pervaporation, which combines the best of nanofiltration and old-school heat treatment. There is also an experimental method called adsorption extraction, where the beer is forced to percolate through a column lined with minerals called zeolites that selectively grab the ethanol along with other undesirable molecules.

Combinations of techniques have a lot to offer, says Ghesti. And according to Tom Hallett, who runs the Steady Drinker website, brewers are also introducing new yeast varieties to add interesting flavours. Physics plus biology looks like a potent cocktail.

SEVENTYFOUR IMAGES/ALAMY

Tinkering with the fermentation process is one way to lower the alcohol content of drinks

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overall, it needs to go way up much higher than it is at the moment," says Anderson.

The most effective way to achieve that is a societal shift. "I think what you need is a social norm change… to make it more socially acceptable for drinkers to have alcohol-free beer," says Anderson. Bringing about such a shift is easier said than done, especially when nolo beer isn't widely available in the form that many people drink beer: in a big glass in a bar straight from the tap. "For some heavy-beer-drinking men, I think there is a social stigma that they would look wimpish if they picked up the alcohol-free," says Anderson. "If you could keep it on draft it would be brilliant."

There may be lessons to be learned from places where nolo drinks have taken off, including Germany, Poland and Spain, which are all in the global top 10 of beer-swilling countries on a per capita basis. The Social Market Foundation says that about 14 per cent of all beers consumed in Spain are now alcohol-free. But appearances can be deceptive and local circumstances matter. Spain's success has been attributed to a preference for ice-cold lager, which nolo beers mimic well but which may not translate to colder climates. In Poland, meanwhile, 5 per cent of the beer market is nolo, and sales grew by 60 per cent in 2019. But this isn't actually an indicator of health-conscious switching, because nolo beers are replacing sales of carbonated soft drinks, rather than full-strength beer.

IGOR ALECSANDER/GETTY IMAGES

Some alcohol-free beers are marketed as isotonic sports drinks

"About 14 per cent of all beers consumed in Spain are now alcohol-free"

Image problem

We may have more to learn from the US. The country is the second-biggest market for nolo after Germany and demand is forecast to grow about 10 per cent a year until 2024 despite some strong cultural barriers.

"Low-alcohol beer in the US suffers from an image problem," says Colleen Myles at Texas State University. This is, in part, a hangover from prohibition when "near beer" (less than 0.5 per cent ABV) was legal but horrible. It was mostly made by incomplete fermentation (see "Getting to zero", page 37), which, unsurprisingly, tends to generate beer that tastes more like raw malt and hops. One prohibition-era critic described near beer as a "wishy-washy, thin, ill-tasting, discouraging sort of slop".

But US cultural resistance is weakening as the beers get more interesting and consumers embrace healthier and less-fattening lifestyles. Avoidance of drink-driving is also a factor helping the nolo market in the US, says Myles.

Ultimately, says Anderson, nolo beers might be just a drop in the barrel of what is needed to reduce the harms of alcohol. A more effective intervention might be to persuade drinks companies to marginally reduce the amount of alcohol in their standard drinks, in much the same way that the food industry has gradually dialled down added salt and sugar.

If you reduce alcohol levels in beer by about a tenth, from say 5 per cent to 4.5 per cent, most drinkers won't notice, he says. "And what the evidence shows is that people don't compensate, they don't drink more pints, so obviously they're going to drink less alcohol. That's where you get the real benefit."

I would happily switch from 5 per cent to 4.5 per cent, but I am also captivated by the possibilities of nolo drinks. According to Hallett, a mistake that newcomers make is to expect the beers to be identical to their alcohol-soaked favourites, when in fact they are a different experience. "For me, it's a comparison against other non-alcoholic drinks that I could drink but are not that exciting," he says.

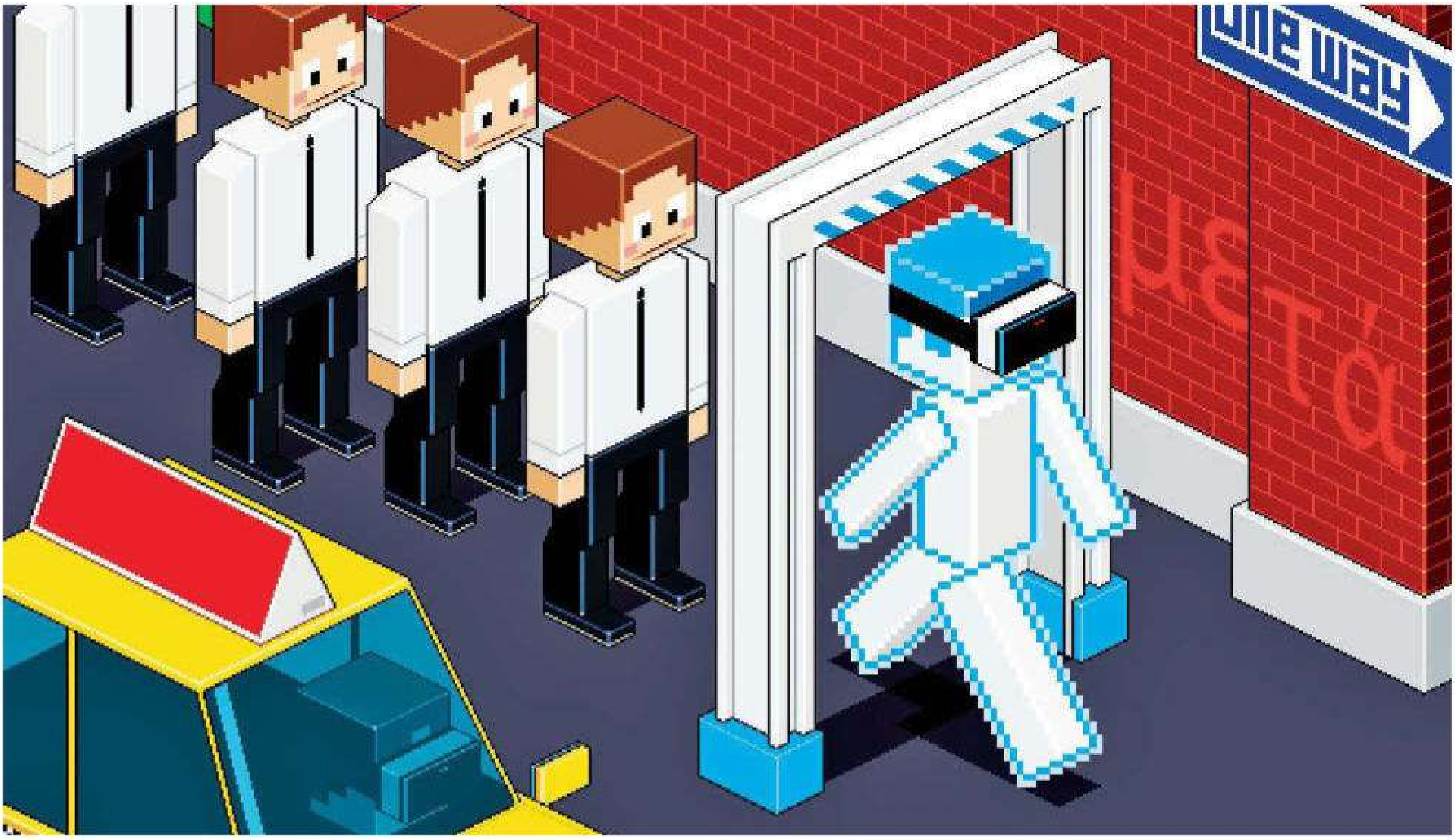
Removing alcohol affects the taste and mouthfeel of a drink, but perhaps less than you might imagine. Last year, researchers at the University of Valladolid in Spain assembled a panel of professional wine and beer tasters to compare six full-strength and 10 nolo beers on a set of sensory attributes: fizziness, body, sweetness, bitterness, astringency, flavour persistence, odour and taste. The only significant differences they reported were in sweetness and bitterness, with nolo products consistently sweeter and less bitter.

On the other hand, some regular beers rely on alcohol to mask a multitude of sins in flavour and aroma. Nolo beers have nowhere to hide, and so open up a new sensory world. I think we can all raise a glass to that. ∎

Graham Lawton is a staff writer at *New Scientist* and author of *This Book Could Save Your Life*. You can follow him @grahamlawton

Welcome to the metaverse

Facebook's rebrand has produced a new tech uber-buzzword. What does it mean for us, asks **Chris Stokel-Walker**



SUPERTOTTO

HIRO PROTAGONIST doesn't see much promise for his future. Stuck in a dead-end job in a world where traditional money has been supplanted by encrypted alternatives and a few big companies shape things to their own ends, he struggles to make ends meet following a global economic collapse. To escape, he slips on virtual reality goggles to visit a place called the metaverse, where his digital avatar walks the streets of a more interesting, engaging, inclusive world.

This vision of a 21st-century reality comes from *Snow Crash,* a 1992 book by science fiction writer Neal Stephenson. But wind forward to 2022, and one large and powerful company is certainly betting all on Protagonist's escape route. In October 2021, Facebook rebranded itself as Meta, and founder Mark Zuckerberg set a goal for a billion people worldwide to join its version of the metaverse by the end of the 2020s. It committed at least $10 billion last year alone to make that a reality.

Zuckerberg isn't the only one latching on to a radical vision in which we go to work, seek entertainment and connect with each other not in a physical world, but in a virtual reality. The buzz surrounding the metaverse raises many questions. Chief among them are, what exactly is the metaverse, is it really just around the corner and, if so, do we actually want it? ›

FUNNY-LOOKING THINGS

Computer-generated graphics are now able to digitally replicate long-dead actors in Hollywood movies, and deepfake video technology makes it possible to fool even the most sceptical viewer. Yet log on to the mooted iterations of the metaverse from the likes of Meta, Microsoft and Roblox (see main story), and the blocky, cartoonish graphics still look like they have been imported from an old generation of video game consoles. It raises the question: why does the metaverse look like it does, and when, if ever, will that change?

"Reproducing natural forms, and particularly natural forms we are very sensitive to, like other humans, is super-difficult," says Steve Benford at the University of Nottingham, UK. The simplest explanation for the cartoonish rendering is the strain more realistic representations would place on processors and online connections. "My guess is that it would be related to technical limitations," says Nick Kelly at Queensland University of Technology, Australia. "As mass multiplayer games have shown, it's really difficult to have 500,000 people all interacting simultaneously without huge lag."

Then there is the "uncanny valley". This term, coined in the 1970s by robotics professor Masahiro Mori, describes how lifelike robots can provoke feelings of revulsion or horror if they aren't quite right. It has since been extended to graphical renderings of humans in video games and movies. If and when metaverse technology becomes more widespread, the unease that such avatars generate will have to be confronted – and it could mean that the graphics of the metaverse always remain in the realms of the cartoonish.

"If our entire lives are lived out online, there is more opportunity to sell us advertising"

New Scientist events
Philosopher David Chalmers discusses virtual worlds on 10 February **newscientist.com/events**

BEWARE OF DOG!

For the company now known as Meta, you can see the attraction in the metaverse. The firm currently makes its money selling advertising based on our interactions with Facebook, its core app. But that only gives the firm visibility over the parts of our lives that we choose to put on Facebook. If our entire lives – or at least a far greater proportion of them – are conducted online, the opportunity to make big bucks selling advertising becomes that much greater.

Facebook's metamorphosis certainly amped up the metaverse hype. Almost 160 companies mentioned the metaverse in their earnings statements in 2021, according to financial research firm Sentieo, 93 of them after the Facebook rebrand. "It's a lot like when the 'internet of things' was first coming about, and the phrase started to be on everybody's lips," says Nick Kelly, who researches interaction design at Queensland University of Technology in Australia.

For Kelly, the metaverse is just the latest in a continuum of technological development that includes the gramophone bringing the sound of live music into people's living rooms and televisions pumping out alternative audiovisual realities. "It's about this trend we have of designing new experiences," he says.

The core vision in this case is to reimagine the internet and all the services as a physical, three-dimensional thing with a spatial reality that we – or rather our digital avatars – can navigate. "In this future, you will be able to teleport instantly as a hologram to be at the office without a commute, at a concert with friends, or in your parents' living room to catch up," wrote Zuckerberg when announcing Facebook's rebranding. That virtual life could seamlessly blend with a "real" one: you might "walk" along to your favourite virtual ice-cream parlour, say, interact with a virtual assistant to pick your flavours – then see it arrive at your real door, couriered by a real person.

That detail might be novel, but there is nothing particularly new about the basic idea. Back in 2002, before Facebook even existed, games studio Linden Lab brought out *Second Life*, an immersive 3D world where you could hang out with friends, go to nightclubs, and buy and sell items. A large amount of ink was spilled on the dawn of a new world that would in time supplant our regular one. In time, it just... didn't. At its peak in 2006, *Second Life* had a gross domestic product (GDP) of $64 million and a million users. But it quickly petered out, and is now inhabited only by a diehard few.

Reality plays catch-up

Why so? "The infrastructure just wasn't there," says Steve Benford, co-founder of the Mixed Reality Laboratory at the University of Nottingham, UK. "The vision was a long way ahead of what could be done." In the UK in 2002, there were just over a million broadband connections, compared with 27 million now. The most powerful commercially available computer microchips had some 220 million transistors; the figure today is 40 billion. "Now the infrastructure is beginning to catch up – and perhaps parts of the metaverse can be delivered," says Benford.

Perhaps. "There are many different technologies that enable this greater vision of the metaverse as a convergence of physical and digital – or our digital lifestyles catching up to our physical lives," says Cathy Hackl at the Futures Intelligence Group consultancy. Some, such as virtual reality goggles and the blockchain, already exist. Others, such as haptic technologies to make virtual touch experiences feel "real", are in development (see "Keystones of the metaverse", page 42).

That doesn't mean the technology to make a full-fat version of the metaverse is anywhere near ready, though. For a start, internet speeds, while vastly improved, still lag behind what is needed. "There's a lot of data to ship around in the metaverse, and it has to get to a lot of people globally," says Benford. "You're going to need amazing levels of connectivity, 5G and beyond," says Hackl. That will require equipment such as edge computing, which aims to distribute the computation done on cloud servers more widely and bring it closer to individual users, as well as machine-learning algorithms that are capable of responding in ›

KEYSTONES OF THE METAVERSE

Many of the technologies necessary to make an immersive virtual version of the physical world already exist to at least some extent.

AUGMENTED REALITY

This involves overlaying a virtual environment on top of real life, often using special glasses or a phone. Google Glass, an attempt by the search giant to do something similar, flopped in the early 2010s. Some primitive, but common, examples now include Snapchat's Lenses that, for example, turn you into a dog when you open your mouth. Meta is developing a pair of augmented reality glasses called Nazaré that CEO Mark Zuckerberg hopes will become as ubiquitous as mobile phones are today.

VIRTUAL REALITY

Plugging yourself into virtual reality usually involves wearing a headset, often accompanied by handheld motion controllers, and seeing your entire field of vision and other elements of your senses overtaken by a digital world. Your movements map onto your digital avatar's, allowing you to traverse a virtual universe. Entry into Meta's version will probably require a pair of virtual reality goggles made by Oculus, a company Facebook bought in 2014.

HAPTICS

Touch is a big thing missing from many extended virtual reality experiences. Meta's AI research department is one of many trying to make the metaverse more touch-responsive using haptic technology, which applies force or vibration to your skin to mimic real physical touch.

BLOCKCHAIN

A distributed, decentralised ledger of information that is held across multiple users, the blockchain could be the digital key to the metaverse. Its immutable records would allow users to have the confidence to transact their business online without worrying about being scammed.

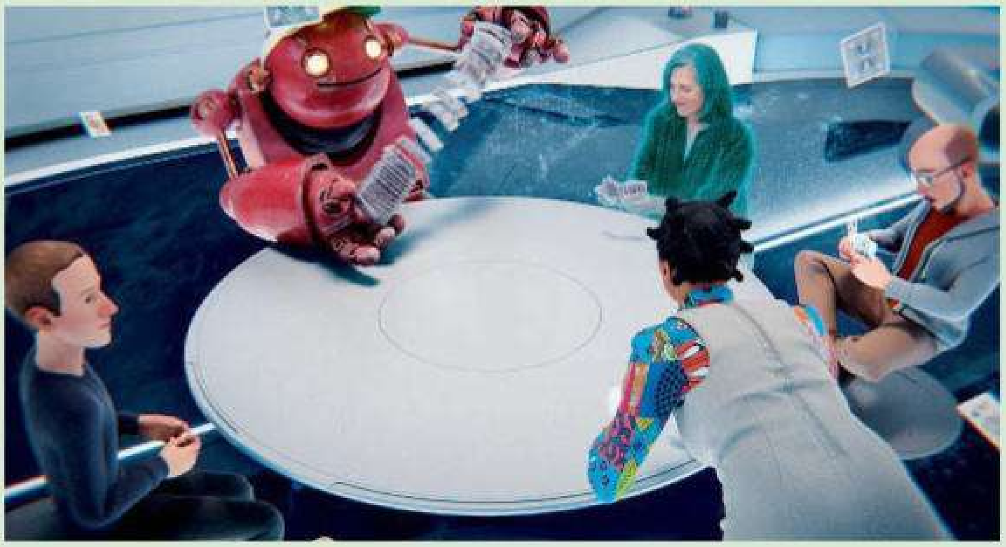
MIXED REALITY

Combining elements of the real world and the virtual, mixed reality is a broad-brush term for things that often don't fit into augmented or virtual reality.

EXTENDED REALITY

Extended reality is a catch-all term to cover the likes of augmented reality, virtual reality and mixed reality. Taken together, it is a key area of research for academia and industry alike.

Mark Zuckerberg's Meta is developing tech for us all to enter the metaverse



META

real time to direct data to users more quickly.

Even with such advances, our ability to make truly immersive metaverse experiences is likely to be limited for the foreseeable future. Producing realistic graphical representations, particularly of other humans, is one persistent sticking point in this (see "Funny-looking things", page 40).

Incorporating the full range of sensory experience, including taste and smell, is also yet to be addressed. Just as space-age cartoons like *The Jetsons* envisaged a world of flying cars and robot butlers in the year 2062 that seems unlikely to come to fruition, so the most outlandish visions of the metaverse still seem far away. "We're seeing glimpses of the metaverse," says Hackl. "It's being built as we speak."

What it is being built for is another open question. At Meta's virtual rebranding press conference, reporters found themselves typing at digital facsimiles of laptop keyboards at a facsimile of a conference room desk, listening to Zuckerberg's digital avatar opining on a facsimile of a desk chair. This world of work is what one of the few firms big enough to match Meta punch for punch, Microsoft, seems to be aiming at with its own metaverse efforts. Microsoft's mixed reality system, called Mesh, has been integrated into its Teams collaboration and video conferencing app, with a view to offering 3D virtual avatars of meeting participants and computer-generated meeting rooms in the first half of 2022.

Physical disconnect

Many are sceptical about this vision, however: the most common complaint heard about the hybrid or fully remote working practices that many office workers have adopted during coronavirus lockdowns over the past two years is the lack of physical connection. This seems unlikely to be enhanced by a layer of cartoonish graphics on top of a video call.

Other avenues might be more fruitful. "The obvious wins for me are in entertainment and socialising – stuff you want to do where you hang out with people who are not nearby," says Benford. "A number of us now realise you can do nice things with remote friends and families online." Digital concerts are a case in point where the metaverse is already

Pop star Ariana Grande gave a concert in *Fortnite*'s virtual world in August 2021

EPIC GAMES

> **"Some or many of the metaverses now being built may end up as ghost towns"**

becoming reality. The video game *Fortnite* and the game development platform Roblox, which encourages its users to build their own worlds, have both hosted concerts by digital representations of real-life pop stars during the pandemic.

Some 47 million people use the Roblox platform every day, amounting to 11.2 billion "hours engaged" in the third quarter of 2021, according to the company. With their experience in building immersive worlds and their already enthusiastic user bases, the gaming companies could be a significant challenge to Meta's vision of a metaverse built from scratch that it controls. Just as the "format wars" of the 1970s and 1980s saw VHS and Betamax video tapes battle for supremacy, with one eventually winning out, so there is a real possibility that, like *Second Life*, one or several of the many metaverses now being built will end up as ghost towns.

Hackl hopes for an open metaverse, with interoperability between different platforms allowing your digital avatar to leap to another world just as we can easily travel from one city to another. That is a model that the European Union is already pushing for with social messaging apps in its draft Digital Markets Act proposals, meaning that you don't need to sign up to a certain app to talk to your friends just because they aren't on the same services you are.

All that swerves the real multibillion-dollar question, however: whether we will want to abandon our "meatverse", where we press flesh, touch and feel and interact with fellow humans, for the metaverse where, the development of technologies such as haptics notwithstanding, we are gesturing at digital alternatives. Even with its change in name, Meta's involvement may give some potential users pause for thought, mired as the company is in negative publicity ever since the 2018 Cambridge Analytica scandal, in which users were targeted for political advertising.

The hype might serve to pose the question of what we might want from expanded digital worlds, and how that compares with the visions of the metaverse on offer. "There's this idea that it's openness; that it's actually expanding the possibilities of your life by entering the metaverse," says Kelly. "I would argue it's doing the opposite. It appears to be open in the same way that the internet is open: that the actual practicalities of who is able to create that world is extremely unequal."

He sees the idea of the metaverse being coded by, and inevitably shaped in the image of, Meta's workers – rich, predominantly white and based in Silicon Valley. It is a "very constraining idea that will narrow the scope of human lives when they spend time in this hypothesised metaverse", says Kelly.

When Hiro Protagonist donned his virtual reality goggles in *Snow Crash*, he was doing so to escape the horrors of his life. He ended up finding the metaverse equally unpalatable, populated by gangsters and ne'er-do-wells. Social media platforms such as Facebook have shown us how virtual platforms can end up amplifying undesirable currents in the world outside – with knock-on effects in the real sphere. It is time to consider, perhaps, how we can ensure that whatever the metaverse ends up being, it ends up being what we want. ■

Chris Stokel-Walker is a freelance technology writer based in Newcastle, UK

The power of paradoxes

Grasping the role of human intuition in mind-bending logic puzzles can help us all think more clearly, says philosopher **Margaret Cuonzo**

A WOMAN once approached me with a curious problem concerning her husband. Like most people who choose to get married, she had promised to love her spouse to the exclusion of all others. But there was a problem: according to her, the man she married simply wasn't the same person any more. He had the same name and career, the same memories and skills. But over many years, an accumulation of small changes had, she felt, made her husband a completely different person.

This woman had approached me not because I'm an expert in matters of the heart, but because I had just given a talk about paradoxes. These puzzles have entertained and perplexed us for millennia. They force us to grapple with some of the deepest matters of logic and meaning. What does it mean for something to be "the same", for instance?

I couldn't offer the woman any simple answers. I reminded her that she had probably changed quite a bit since her youth too. And I pointed out that sometimes our intuitions about concepts like identity can be unhelpful.

In fact, the point goes well beyond relationships. Chewing over paradoxes can show us places where our intuitions need tweaking, and this applies everywhere from the foundations of mathematics to social media and our efforts to live more sustainable lives. Paradoxes have helped thinkers resculpt our understanding of key concepts and attain fresh scientific insights time and again. Now, a new way of thinking through paradoxes is emerging, one that holds promise because it puts our mushy human intuition front and centre.

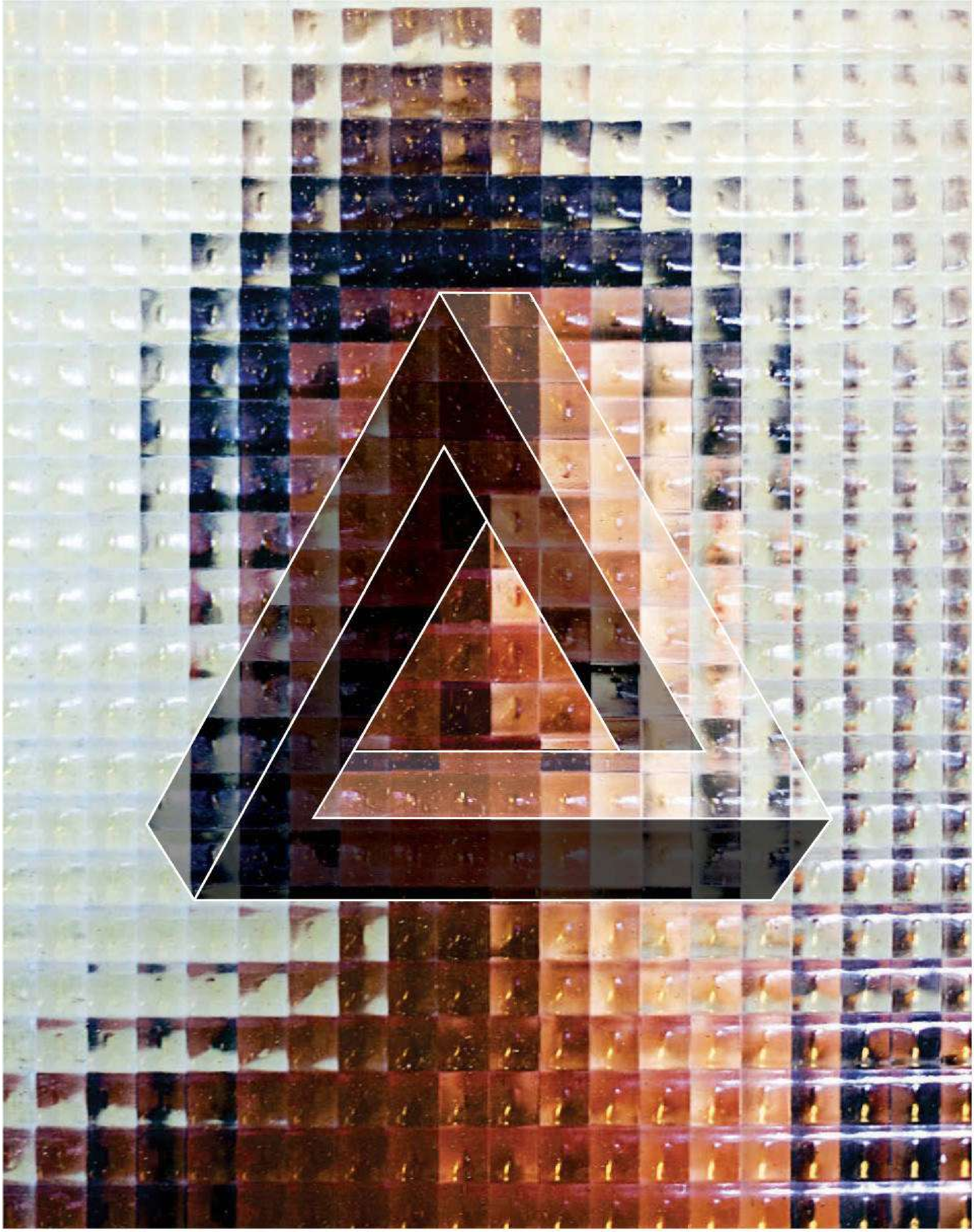
One reasonable way to define a paradox is as "a set of mutually inconsistent claims, each of which appears to be true". One of the oldest and most famous of these puzzles is Zeno's dichotomy paradox, developed by Zeno of Elea, a thinker who lived in Greece in the 5th century BC. Imagine a person walking from point A to point B. To reach point B, they first have to walk half the distance, and this takes some finite amount of time. When they get halfway, they still have to walk halfway between where they are now and point B, and this also takes a finite amount of time, albeit a little less. Zeno carried on this argument to apparently show that, no matter how far you have travelled towards point B, you will always still have to walk halfway from your current position to point B and this takes at least some amount of time. The conclusion is that all journeys should take an infinite amount of time – yet clearly that isn't true.

When we encounter a paradox, our instinct is that something has gone wrong. Contradictions like this shouldn't exist and we want to solve or explain away the inconsistencies. In the case of Zeno's paradox, mathematicians have since discovered that it is possible to divide up a distance into an infinite number of portions – but also to add up that infinite series and get a result that is finite. For most of us, that seems counter-intuitive, but it is a truth showing that reality doesn't always conform to our preconceptions.

In my work, I have identified a number of general strategies that logicians use to tackle paradoxes. For instance, the aforementioned solution to Zeno's paradox is an example of what I call the "odd guy out" strategy, where we spot that one of the premises of the paradox is dodgy. Sometimes, paradoxes are extremely difficult to explain away, and in these cases logicians can employ what I call the "detour", where you admit that the paradox can't be solved on its own terms, but propose that some deep assumption about reality needs revising.

This kind of thinking has been helpful on many occasions, not least through the famous Schrödinger's cat paradox, which has helped us interrogate the true meaning of quantum theory for decades. But using logic alone to analyse paradoxes ignores an important element of what makes them so engrossing in the first place. A lot of the language used to discuss paradoxes uses terms like "seem", "apparently" or "appears to show", which subtly demonstrates that human understanding is at the core of how paradoxes work. Paradoxes don't exist in a vacuum, they are puzzles that take shape in our minds.

This is what prompted me to begin developing a new way of analysing paradoxes a few years ago. My method puts us, the readers of the paradox, at the heart of things. It hinges on an old idea called subjective probability, often used in maths but not applied to paradoxes before. Subjective probability is the degree to which a rational person will believe something. Take a statement like "two plus ›



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two equals four". This would have a subjective probability of 1, in other words it is certain. I would put "The bus will be late" at be 0.75; more likely than not. "The next coin toss will be a heads" would get a value of 0.5. And "two plus two equals seven" would be 0. Subjective probabilities can vary from person to person, but not usually by much. In this story, the values I give are my choices, but they are likely to be similar to what you would assign.

When we encounter a paradox, we can break it down into a set of claims and a conclusion and then evaluate the subjective probability of each. To see how this works, let's try it with a deceptively simple puzzle called the liar paradox, which comes in the form of a single sentence: "This sentence is false." We will call this sentence "L". If L is true, then L, which claims that L is false, must be false. And if L is false, then it is false that what L says is false, so it would then be true. And since L is a declarative sentence, and should therefore be either true or false, it seems to follow that L is both true and false. When we look at the paradox as a set of claims and give their subjective probabilities in parentheses we get the following:

1. If L is true, then it is false (1.0)
2. If L is false, then it is true (1.0)
3. L is either true or false (0.9)

Conclusion: Therefore, L is both true and false (0)

The subjective probability of the parts of this paradox are high, yet the conclusion seems like nonsense. The first claim, that if the sentence is true, then it is false, follows from the meaning of the sentence. So does the second claim. As for the third, it is an oft-cited feature of declarative sentences that they are true or false, and L takes the form of a declarative sentence. Yet the conclusion is an outright contradiction.

One advantage of my method is that it helps us see how strong a paradox is. Assuming we are using valid logical reasoning, then the greater the disparity between the subjective probabilities of the claims and the final conclusion, the stronger the paradox. The liar paradox is a strong paradox.

Another benefit of this approach is that it

> **"Paradoxes don't exist in a vacuum, they are puzzles that take shape in our minds"**

Both true and false

It feels like common sense to say that all statements must be true or false. Aristotle called it "the most certain of principles". But is it? Some philosophers hold the radical view that statements can be both true and false, which is called dialetheism. This view is gaining traction among logicians because of the way it can help with paradoxes.

What are we to make of this strange idea? One big problem for dialetheism is that it allows direct contradictions to exist and this leads to a well-known difficulty in logic called the problem of explosion. If it is fine to say it is raining and not raining, then our entire basis for belief and action blows up.

One reason this is so tricky is that you can use a contradiction to prove anything you like. To see how this works, let's take the sentence "Alice is pregnant" and call it A. According to dialetheism, we can say that both A and Not A are true. Now we can construct a statement of logic in which two options are present, A and B, where A is the sentence about Alice and B can be absolutely anything, such as "bread is expensive". We can say that either A or B must be true, because we have already assumed that A is true as part of our starting assumptions. If A or B is true and so is Not A (which, again, was part of our starting point) then, according to a rule of inference called disjunctive syllogism, we can conclude that B is true.

All this seems like an indictment of dialetheism. Surely, we shouldn't be able to use a contradiction to prove some unrelated fact chosen more or less at random? But on the other hand, strong mind-benders like the liar paradox (see main story) force us to give ideas like this a chance. Plus, dialetheists have developed clever ways of denying that disjunctive syllogism is always valid.

Toying with the foundations of logic in this way is a worthwhile pursuit. Much of science is based on logical reasoning and there is no guarantee that the classical rules are the perfect or only tools we need. The human brain works in a more malleable fashion most of the time, with grey areas and contradictions. Perhaps our logic would be better if it did likewise.

suggests a way to tackle paradoxes – by finding a way to lower the subjective probability of some of the claims. In the liar paradox, we can see that premise 3 has the lowest subjective probability. Premises 1 and 2 are true as a direct result from the meaning of L. Premise 3, though, assumes that every statement is either true or false. This seems intuitively right, but there is that word – intuition. Perhaps we are on to something here.

One legitimate response to this paradox is to say it highlights a problem with our intuition about truth and falsehood. The philosopher Alfred Tarski pointed out that a peculiar feature of languages like English is that they don't separate out the expressions used to speak about everyday facts, such as "the book is on the table", from the expressions that refer to the language itself, like "the sentence about the book is true". Tarski didn't think this would be a practical problem for most of us. But he did realise that it would cause trouble in certain circumstances, such as when a linguist is analysing the structure of a language. He proposed that in those situations we should employ a separate artificial meta-language, typically based in mathematics, to help us talk about the language being analysed.

SHUTTERSTOCK/BRILLIANTEYE

This might seem abstract, but it tells us two interesting things. First, sometimes it is helpful to separate out logical arguments to avoid self-reference problems. Second, it hints that we may need to question our intuition about the fundamental nature of truth (see "Both true and false", left).

Paradoxes aren't solely relevant to semantics and logic, nor are they always ancient puzzles. As I have explored paradoxes, I have seen how they occur in everyday life and draw attention to recurring issues with how we think about the world.

One puzzle that keeps rearing its head is known as the Jevons paradox. It was discovered in the 1850s by the economist and logician William Stanley Jevons in the context of coal. It seems to show that by increasing the fuel efficiency of machines, you end up using more fuel overall. Here is how it looks, point by point, together with subjective probabilities:

1. Increasing the fuel efficiency of a piece of technology will allow for less consumption of fuel for the same amount of work (0.9)
2. A piece of technology that will allow for less consumption of fuel for the same amount of work will be used more often (0.8)
3. Increasing the use of a piece of technology will increase the amount of overall fuel consumption (0.9)

Conclusion: Therefore the increasing fuel efficiency of a piece of technology will increase the amount of overall fuel consumption (0.3)

Even on a first read, this paradox feels surprising, but less deep than the liar paradox. It turns out there is an way to increase the subjective probability of the conclusion. Think of what has happened as internet speeds have gone up over the past two decades. We might have assumed that faster speeds would mean that people take less time to complete tasks and so overall time spent online would decrease. However, the increased speed actually opened up new opportunities and people ended up spending more time online. This paradox teaches us that changes to part of a system don't necessarily get multiplied at a constant rate as that improvement rolls out across the whole system. ›

The Jevons paradox is crucially important today as we drive to reduce our carbon emissions. As a technology becomes more fuel efficient, it is tempting to use it more often. But this can result in what is called a rebound effect. All of us – especially those in power – must understand this as we pursue net-zero emissions targets. Simply increasing fuel efficiency is at best an insufficient measure. We also need zero-carbon technologies and interventions such as taxes that prod human behaviour in the right direction.

An even more prescient paradox today is the paradox of tolerance, expressed most famously by the philosopher Karl Popper in 1945. It begins with the seemingly unproblematic idea that being tolerant means tolerating all views, but trouble quickly follows:

GOLUBOVY/GETTY IMAGES

Trying to be tolerant online can tie us up in paradoxes

1. To be completely tolerant, a society must allow the expression of all views (0.9)
2. Intolerant views are views (1.0)
3. To be completely tolerant, a society must allow the expression of intolerant views (0.9)
4. The expression of intolerant views creates intolerance, either in thought or action (0.9)

Conclusions: Therefore, to be completely tolerant, a society must allow the creation of intolerance (0)

If we apply subjective probability, we see this is a deep paradox. There is no straightforward way of lowering the probability of any of the claims, which suggests we might need to modify our intuitions about tolerance at a higher level. One way we can do this draws from Tarski's analysis of the liar paradox. We might say that tolerance operates at two levels: individual views and a meta-level notion of tolerance that floats above those views and says that both tolerant and intolerant views are tolerated. However, what wouldn't be tolerated under the meta-notion is any intolerant view that seeks to restrict the ground rule of tolerance itself. A claim like "The xs are bad" may be an intolerant view of any x, but such a view can exist in this tolerant system without paradox. However, "The xs should not have the right to express their views" cannot, because it violates the meta-level rules of tolerant discourse.

> **"The Jevons paradox is important as we drive to reduce carbon emissions"**

We see the fallout of this paradox all around us in the way that social media companies grapple with intolerant views – racism, sexism, xenophobia and more – on their platforms. Many social media sites, citing the need for the free expression of ideas, have been hesitant to ban those who espouse conspiracy theories, misinformation and intolerance. A fuller understanding of the paradox of tolerance helps us see why this is reasonable but also where the boundaries ought to lie. When the views promoted restrict the abilities of others to express their views, then this is a violation of the ground rule of tolerance.

Identifying and rethinking paradoxes can help us all understand the world around us a little better. Engaging with them may cause us to question our intuitions and sometimes that can feel frightening. But next time you encounter one it is worth stopping to ponder for a while. When you come away you might not be quite the same person – whatever that means. ▮

Margaret Cuonzo is a philosopher at Long Island University Brooklyn in New York and the author of *Paradox* (MIT Press)

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A MIND-BLOWING
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The back pages

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Science of gardening

As cold as brassicas

Winter is purple sprouting broccoli's time to shine. **Clare Wilson** reveals its origins, and how best to grow it in your garden

Clare Wilson is a reporter at *New Scientist* and writes about everything life-science related. Her favourite place is her allotment @ClareWilsonMed

What you need

Purple sprouting broccoli seeds
Netting
Garden hoops or bamboo canes and old hosepipe

GAP PHOTOS/TIM GAINEY

IN THE depths of the UK winter, most of my vegetable beds are bare, except for my star performer: purple sprouting broccoli. It is in the middle of its fabulous January growth spurt.

This giant of a broccoli plant is arguably the queen of the brassica family of vegetables. Also known as winter sprouting broccoli, it is very tolerant of cold, and requires several weeks of cold weather before it puts forth its flower buds and becomes ready to harvest.

Unlike ordinary broccoli plants, which have a single large head and are usually harvested by autumn, purple sprouting broccoli has multiple small florets as side shoots from the main one. The chief eating pleasure, however, comes from the stalk, which is sweet and delicious after the cold drives its cells to convert their starch to sugar, lowering their freezing point.

The brassica family is diverse and eaten all over the world. Just one species, *Brassica oleracea*, includes two kinds of broccoli, cauliflower, cabbage, Brussels sprouts, kale, kohlrabi and more, as people have bred it for the development of different traits.

B. oleracea's origins have long been debated, but last year an international collaboration solved the mystery when it genetically sequenced 14 different brassica crops and nine potential wild ancestors.

The researchers found that the ancestor was most likely to be a close relative of a plant called *Brassica cretica*, a gangly weed with cabbage-like leaves that grows on the rocky shores of Greece, Turkey and Lebanon. The shoots of this wild plant are edible.

Similar-looking plants found on the coasts of the UK and other parts of western Europe turned out to be "escapees" that reverted in the wild to their ancestral forms – a sort of "feral cabbage", says Makenzie Mabry, now at the University of Florida, who was involved in the work.

After sowing purple sprouting broccoli in a small pot, you will need about 1 square metre of land per plant. You need to cover it with netting to keep pests away – especially butterflies such as the large white (*Pieris brassicae*). You can buy hoops to hold up a netting tunnel over the plants, but I make my own by sticking lengths of thin cane into the ground along the sides and using sections of old hosepipe to connect the two sides.

Apart from scattering a few slug pellets when the young plants are put in the ground, and watering in the summer, that is about all the attention they need. Crops that produce their harvest in summer typically need more watering and fussing over, but there is more rain and fewer slugs in winter.

Purple sprouting broccoli is a versatile cooking ingredient, but my favourite approach is to briefly microwave it before adding it to a hot wok with garlicky oil, then sprinkling with toasted sesame seeds. ▮

Science of gardening appears every four weeks

Next week

Citizen science

These articles are posted each week at newscientist.com/maker

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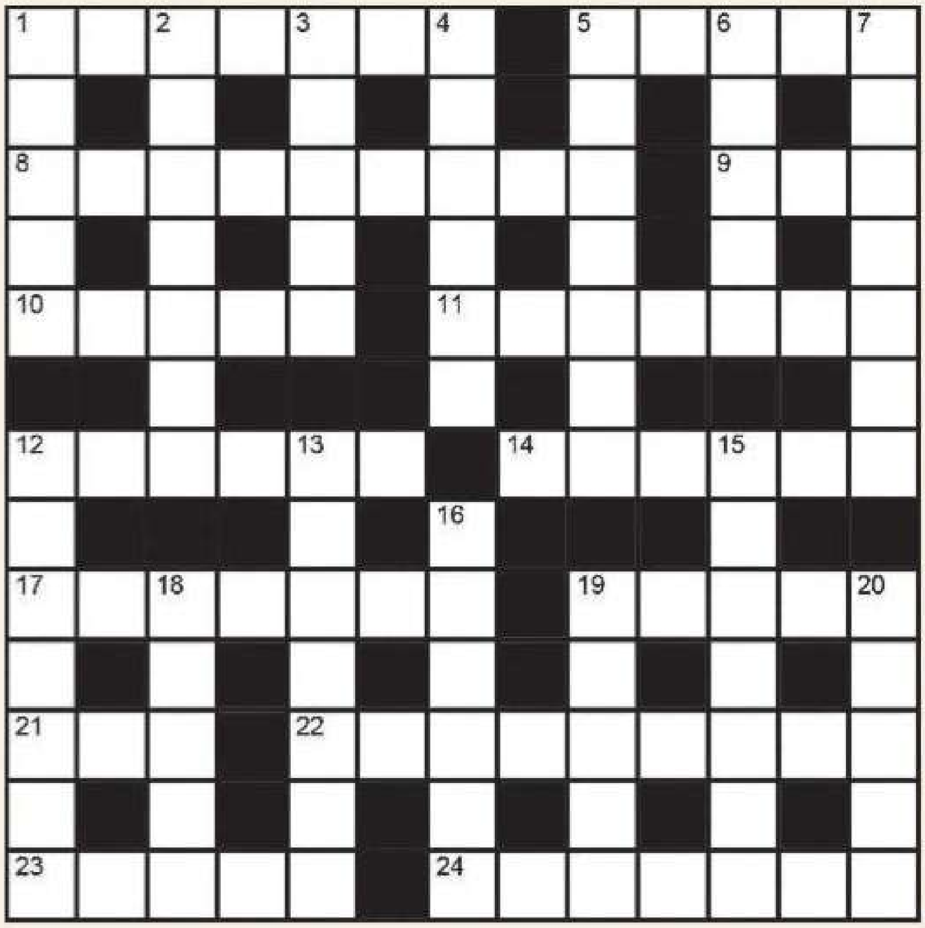

Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Aspirin company protects interior of pill with type of membrane (7)

5 Second-rate green cosmetic (5)

8 Person who drops rubbish dance style gets a fresh start (9)

9/21 Coolant rapidly emptied into random number generators (3,3)

10 Unusual wider convertible (5)

11 Beaufort, for instance, meets one dismissing love triangle (7)

12 The sound is sizeable, watery (6)

14 Track introducing band's poignant quality (6)

17 Dramatic departure of Uncle Rocky (7)

19 Peels fruit, say (5)

21 See 9 Across

22 Animal backbone used in shade of black dye (9)

23 Finally managing to secure organ (5)

24 Absorption process is behind concept of the universe as a whole, first off (7)

DOWN

1 Shattered elbow underneath the deck (5)

2 Top level in extremely large crystalline structure (7)

3 Lied outrageously in support of variable reaction output (5)

4 Vigorous tumult moved away from Rodin sculpture (6)

5 Dig anew into cricket club sitting on a huge amount of information (3,4)

6 In text, you slammed *Dune*: "Excessive" (5)

7 Nye hugs zany scientist who invented the pendulum clock (7)

12 Circle around towards a boat's rear, acting like thrill seekers or otters (7)

13 Under threat, guys served flawlessly (7)

15 Exploit property of minerals described by Mohs (excluding diamonds) (7)

16 Travel crosscheck includes fastener (6)

18 Grey half-moon elevated symbol of resistance (5)

19 Cabinet-maker keeps overturning Sir Isaac Newton's beam splitter (5)

20 Solid sulphur coating key neutralisation products (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #133

1 Where in the body would you find the turbinates?

2 Who are the two creators of the TCP/IP communications protocol, the architecture underpinning the internet?

3 What famous experiment did Thomas Young perform at the start of the 19th century?

4 What is the largest moon in our solar system?

5 Poneratoxin is the primary toxin in which insect's venom?

Answers on page 55

Puzzle

set by Howard Williams

#149 All in a spin

Fairground designer Ferris Caroselli has designed a new ride. Six teacups, each with seats for passengers, spin around a giant stationary dinner plate. Each cup sits on a cog that is 1 metre in diameter, which meshes with a 5-metre diameter cog under the plate, so that the cups spin without slipping.

A mother watched her children on the ride, and counted how often they spun around in one full circuit of the plate. She was slightly surprised at the answer. How many times was it?

Solution next week

Spider survival

I often catch house spiders and release them some distance away. Can they navigate back? If not, what are their chances of survival?

Brian Reffin Smith
Berlin, Germany
The only place to release a house spider is a house. That's their habitat.

Matt Bertone
North Carolina State University, US
First, it depends on the type of spider. If it is one of the more active ground spiders, like a wolf or sac spider, it would appreciate being released outdoors. This is because these spiders often accidentally come into homes, where there isn't a lot of prey for them. If they become trapped for too long, they can perish, so letting them go live back outside can be a huge favour for them.

Other spiders, like cobweb spiders and cellar spiders, tend to do well in our homes for their entire life. In this case, they can be left alone, but if removed from the house, they will often find the nearest area that is suitable and do their best to survive.

> "Spiders don't have good ways to find their way back to your house, so they find the nearest suitable area and try to survive"

Such spiders don't have good ways to find their way back to your house, and it would require a lot of energy and drive to do so. I would also caution that removing spiders from a home, with a specific temperature and humidity, into an environment that may be drastically different could harm the spider. For instance, if the temperature outside is too cold or hot, it may have negative effects. However, spiders are pretty hardy animals, so moving them usually doesn't cause problems.

All said, spiders are fairly adaptable to local habitats, and most don't require special spaces, except places to build webs or areas to hunt for food.

What causes some materials to glow under ultraviolet light, but not others?

DASRIL ROSZANDI/ANADOLU AGENCY/GETTY IMAGES

This week's new questions

UV glow Why do only some materials glow under UV light? For instance, when I shine my UV torch at a packet, only the price ticket glows bright blue. ***John Cooper**, London, UK*

Pong problem How is it that one's own farts smell tolerable, but other people's smell awful? How does the brain differentiate between the two? ***Tim Hale**, Sheffield, UK*

Me and my brain

If I could somehow replace every atom in my brain one at a time with the same elements, am I mentally still me?

Eric Kvaalen
Les Essarts-le-Roi, France
Yes, you would still mentally be you. In fact, the replacement of brain atoms does happen at a certain rate. Besides which, from the point of view of quantum mechanics, identical atoms are like dollars in a bank account – they don't have individual identities.

Garry Trethewey
Cherryville, South Australia
That is pretty much what actually happens: your brain and body have very few, if any, of their original atoms. In fact, we probably all contain atoms that once were part of Adolf Hitler, Albert Einstein or a dinosaur. Even without the replacement issue, are you mentally the same person you were when you were 2 years old?

Nick Canning
Coleraine, County Londonderry, UK
The problem of personal identity is an ancient one, analogous to a wooden ship undergoing repairs until eventually every plank has been replaced. Is it still the same ship? If all the discarded planks were themselves reassembled, would we have one or two ships? And are you mentally the same person you were as a child, when you were a tenth the mass of your adult self?

If your sense of self at any moment is a product of your material body, associated with the workings of your brain – which depends on all the neurons and their exact location, function and connections established over time – then if you could build an exact replica, it would also feel that it was mentally still you. The content of its self-consciousness would be indistinguishable from yours.

Arnold Taylor
Isle of Wight, UK
It is a fundamental tenet of quantum theory that all atomic particles of the same kind are indistinguishable. Therefore, if all the atoms in a brain were replaced by identical atoms, the person would remain mentally the same, although the states all the atoms were in would probably need to be unchanged as well.

While such a replacement is hypothetical, the same brain pattern could, in principle, recur on another planet in the universe if our evolutionary process were repeated. This is, however, exceedingly improbable. In addition, the vast number of atoms in the brain, or the part of it that determines an individual consciousness, also means that such a recurrence is unlikely to happen anywhere in the universe.

But there are cosmological theories that propose that our universe could be one of infinitely many having the same physical laws. If so, the recurrence of a person's brain pattern becomes almost certain to occur among them, albeit with unimaginable separations in time and space. This would be physical reincarnation, although the individuals would be totally unaware it had happened.

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Tom Gauld
for New Scientist

I HAVE ORDERED SOME NEW SIGNS FOR THE LAB
DANGER OF DEATH
DANGER OF BEWILDERMENT AND PERPLEXITY
DANGER OF A VERY MINOR ACCIDENT THAT NEVERTHELESS REQUIRES LOTS AND LOTS OF PAPERWORK

Pat French
Telford, Shropshire, UK
Surely you and the universe you have created for yourself lie in the electric flux that constantly refreshes and is revised across the synapses and neurons of the brain, rather than in the brain matter itself.

So no, duplicating the atoms of your brain might be like building an identical house, but there wouldn't be anyone at home.

> **"If our universe is one of infinitely many, the recurrence of a person's brain pattern is almost certain to occur among them"**

Magnetic influence

Do magnets have any effects on human cells? (continued)

Mike Follows
Sutton Coldfield, West Midlands, UK
Individual atoms can be affected by magnetic fields, and strong fields can induce nausea, but it isn't clear if there are discernible effects at the cellular level.

We are diamagnetic, which means we are repelled by a magnetic field. Normally, the effect is too small to be observed, however a human could be levitated by a strong enough field.

Electrons orbit the nucleus of each atom. These current loops act like nanoscale electromagnets. Usually, they point in random directions in our bodies so there is no overall magnetic field. But place us in a magnetic field and the current loops adjust so they each form a tiny magnet pointing in the opposite direction to the externally applied field.

Diamagnetism was first observed in 1778, yet was largely forgotten until the late 1990s, when a research group at the University of Nijmegen in the Netherlands levitated a live frog using a magnet with a strength of 10 tesla, which is several orders of magnitude stronger than a typical fridge magnet. The leader of a religious sect got wind of the research and offered £1 million for a machine that could levitate him in front of his congregation. Quite aside from the ethical issues involved, it would have required a specially shaped 40-tesla superconducting magnet.

In 2009, NASA's Jet Propulsion Laboratory successfully levitated mice with the aim of investigating the effect of microgravity on bone and muscle mass. In 1992, volunteers spent 40 hours inside a 4-tesla whole-body magnet with no ill effects. However, people working around 4-tesla magnets have reported experiencing vertigo and nausea. I have felt a bit queasy when moving around an 8-tesla magnet, though this may have been psychosomatic.

Many creatures can navigate using Earth's magnetic field, so humans may well be sensitive to magnetic fields too. However, the jury is still out as to whether there is an effect at the cellular level. Any biological effects are likely to depend on the magnitude of a field or the frequency of a changing field. ▮

Answers

Quick quiz #133
Answers

1 In the nose

2 Vint Cerf and Bob Kahn

3 The double-slit experiment

4 Ganymede, a moon of Jupiter

5 The bullet ant

Quick Crossword #98 *Answers*

ACROSS 6 Ammeter, **9** Fewer, **10** Kilovolts, **11** Epsilon, **13** Strait, **15** Charles Darwin, **19** Upload, **20** Nuclear, **23** Strontium, **24** Range, **26** Lotuses, **27** Epitaxy

DOWN 1 Smew, **2** Sterol, **3** Broken leg, **4** Elevator, **5** Palliative, **6/17/7A** Alfred Russel Wallace, **7** Weld, **8** Ersatz, **12** Sphalerite, **14** Odd number, **16** Realness, **18** Artery, **21** Cervix, **22** AIDS, **25** Near

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#148 Much ado about muffins
Solution

2520 muffins. The total number of muffins must be divisible by 9 (the number of bakers) and 8 (the number of flavours). And because the muffins can be split equally between 2, 3, 4, 5, 6 and 7 tables, the total is divisible by those numbers too. Because the number of muffins is the minimum possible to meet these criteria, the total must have the minimum number of factors (in this case, the lowest prime numbers that can generate all the necessary divisors: 2 x 2 x 2 = 8, and 3 x 3 = 9). These factors are 2 x 2 x 2 x 3 x 3 x 5 x 7 = 2520.

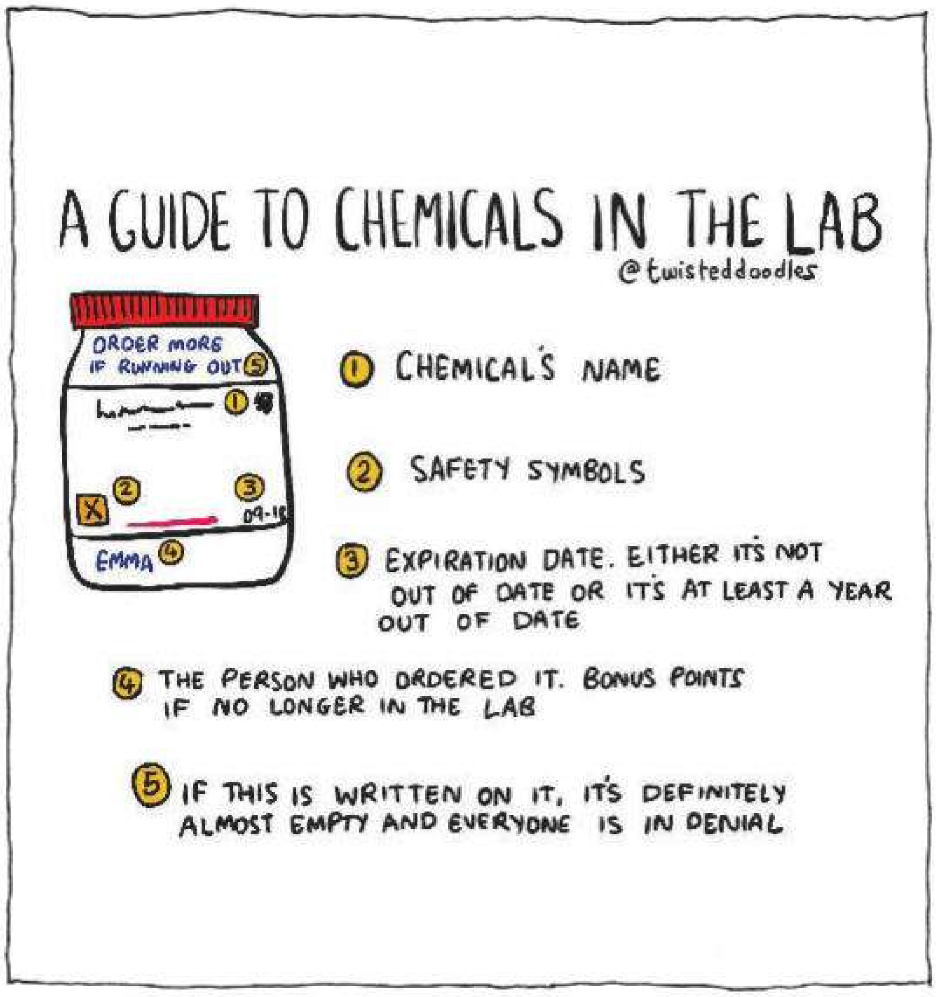
Nailed it

Gazing into the alternative reality featured on the other pages of this magazine, we have mixed feelings. That's a generally valid statement, but it applies especially to the metaverse that The Company Formerly Known As Facebook and others are building (see page 39).

Or it does until we realise it gives our influencer franchise a (glittery) golden opportunity to mention Metaverse Nails™ (patent pending), "the only product in the WORLD that allows you to adorn your digital and physical self with customisable holograms". "Glam wearable tech" is very much our bag – see our tote? It's totes virtual – although our community service order still stands after going too far with Gucci's virtual clothing line in lockdown (3 October 2020). Collectible fashion accessories that interact with a 3D social app to trigger a dazzling range of interactive hologram nail stickers that can be snapped and shared in real time to social networks seem a safer bet.

As was reported last year, TCFKAF might have agreed: shortly after its metamorphosis in October, it briefly suspended the Instagram account, @metaverse, of the driving force behind Metaverse Nails™ (patent pending), Thea-Mai Baumann, for "pretending to be someone else". Far be it for us to question motivations, but if being someone else isn't the point of the metaverse, we aren't sure what is.

Twisteddoodles *for New Scientist*


A GUIDE TO CHEMICALS IN THE LAB
@twisteddoodles
ORDER MORE IF RUNNING OUT ⑤
①
② X
③ 09-18
EMMA ④
① CHEMICAL'S NAME
② SAFETY SYMBOLS
③ EXPIRATION DATE. EITHER IT'S NOT OUT OF DATE OR IT'S AT LEAST A YEAR OUT OF DATE
④ THE PERSON WHO ORDERED IT. BONUS POINTS IF NO LONGER IN THE LAB
⑤ IF THIS IS WRITTEN ON IT, IT'S DEFINITELY ALMOST EMPTY AND EVERYONE IS IN DENIAL

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Flipping the bird

Feedback is relieved to be informed by our man in a hide with a pair of binoculars, Jeff Hecht, that birds are real. For those who hadn't realised there was any doubt, we urge you to marinate – but not for too long – in the social media conspiracy theory that birds used to be real, but were replaced by US government spy drones. The walls of the metaverse being decidedly porous, this has seen billboards pop up in major US cities and a demonstration outside Twitter's headquarters in San Francisco demanding that the company change its logo.

For a while, we had a similar, special theory of avian unreality concerning the implausible, yet undoubtedly ornamental, pelicans of St James's Park in the heart of London's government district. We gave it up on the basis we couldn't work out who ordered the poop. Now, as *The New York Times* revealed last month, the general theory of unreality has been revealed as a prank dreamed up to demonstrate the absurdity of conspiracy theories.

This is all pretty, well, meta. We are left pondering the truth value of the statement "this conspiracy theory is false". While we do so, we offer up the fact that, although birds might exist, fish, reptiles, worms, wasps, jellyfish and a host of other things don't. That isn't a conspiracy, it is phylogenetics.

Look on the buttered side

Andy Bebington intervenes from Croydon, London, with a philosophical solution to the long-standing scientific puzzle in our Twisteddoodles cartoon on 4 December 2021: why toast always lands butter-side down. It is because we buttered the wrong side. We await explanation of how attaching buttered toast to the back of a falling cat retrocausually flips right side to wrong side. It is probably something to do with quantum theory; it usually is.

How low can you go?

Did monkeys really sail the oceans on floating rafts of vegetation? we asked in our super soaraway holiday edition (18/25 December 2021, p 50), answering the question with a firm "yeah but no but yeah".

Brian Horton of the floating raft of vegetation that is Tasmania takes exception, not to that, but to our description of a riverine floating island that "covered an area about the size of two Olympic swimming pools".

"Surely everyone knows that area is measured in football pitches and swimming pools are only for volume," he fumes. "Please ensure that the appropriate units are used in *New Scientist* articles to maintain standards."

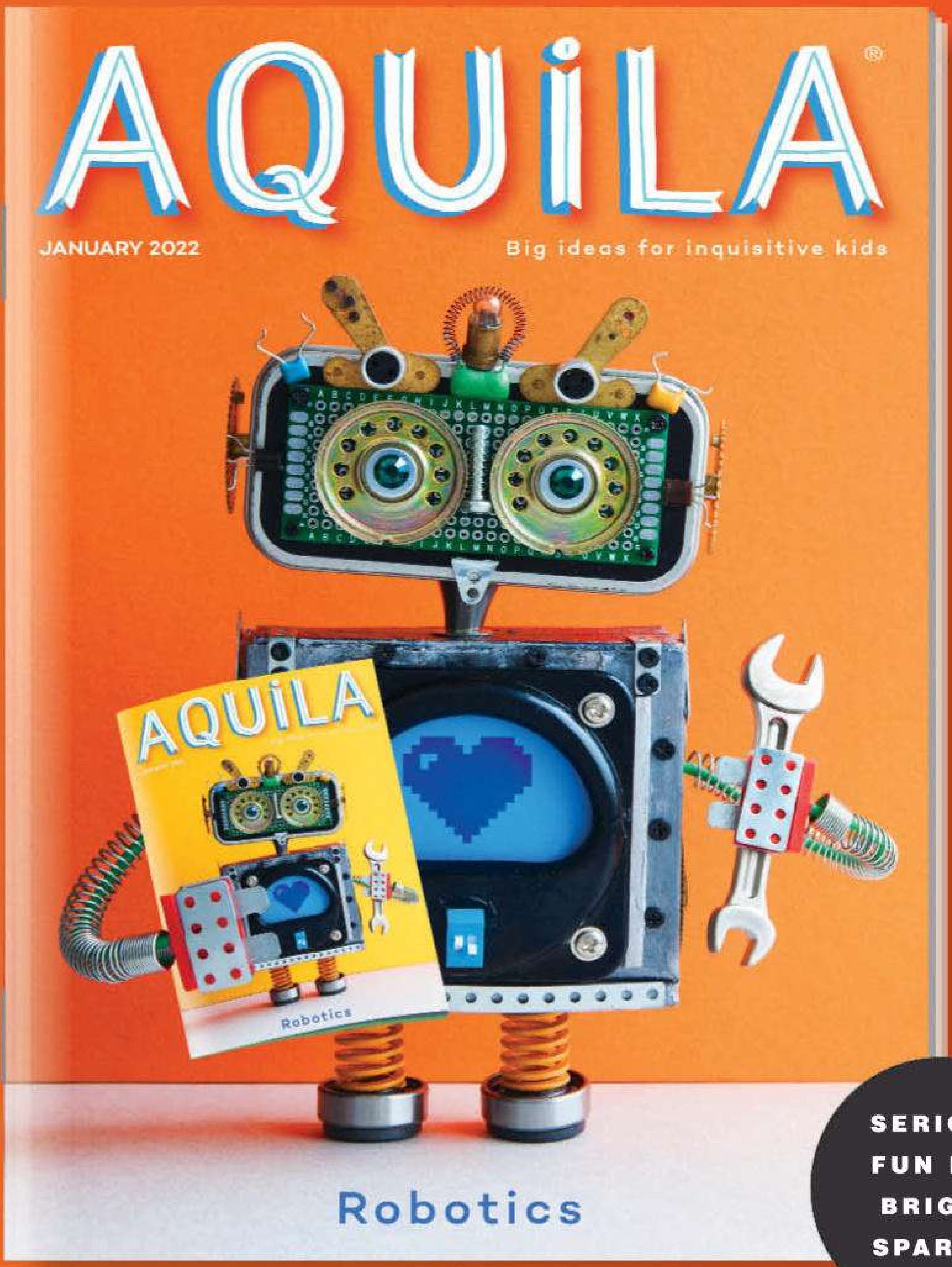
We hear you, Brian, while countering with Malcolm Drury of Ottawa's clipping from a CBC News website article on oil sands tailing ponds in Alberta with a storage capacity "the equivalent volume of more than 560,000 Olympic-sized swimming pools, which would stretch from Edmonton to Melbourne, Australia, and back if placed end-to-end". Measurement standards are clearly slipping – to lower and lower dimensions.

In their element again

Many thanks to those of you who responded to our appeal for elemental names from across the world (11 December 2021). Sergio Frosini from Genoa, Italy, wins the prize of a gram of unobtanium in a virtual tote bag with his list of actors Franca Rame (copper) and Turi Ferro (iron), journalist Tito Stagno (tin) and horror film director Dario Argento (silver).

Sergio further enriches us by informing us that Stagno's principal claim to fame is as the first person in the world to announce the Apollo 11 mission's touchdown on the moon – a full 56 seconds before it happened. Miring ourselves briefly in the nether regions of the Italian-speaking web convinces us that those most liable to bring up this striking instance of retrocausality have well-defined views of the moon landing. Having seen the grainy footage ourselves, we are prepared to accept it was cock-up, not conspiracy. Which is a pretty good guiding principle for life, come to think of it. ▮

"...Advanced & Philosophical, Curious & Puzzling"
Richard Robinson, Brighton Science Festival



SERIOUS FUN FOR BRIGHT SPARKS!

GOOD ROBOT?

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